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WEEKLY 13 August 2022

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This week's issue

On the cover

38 The healing sound of silence
Why we all need the right kind of quiet in our lives

18 Alaskan wildfires
What they mean for the Arctic

Vol 255 No 3399
Cover image: Giulia Neri

42 Five numbers transforming our understanding of the universe

46 Inside the hunt for Earth's first dry land

14 James Webb captures galaxies colliding

12 Gene-edited dogs
20 Weevils to the rescue
20 Quantum Wordle
13 The worst foods for the planet

46 Feature

> **"The Archean Earth of green seas, orange skies and black rocks may all seem quite alien"**

News

8 Ancient chemistry
A 2300-year-old recipe for bronze deciphered

16 Cheating death
An artificial blood substitute keeps organs alive after the heart stops

18 Alaska ablaze
Record-breaking wildfires scorch the Arctic

Views

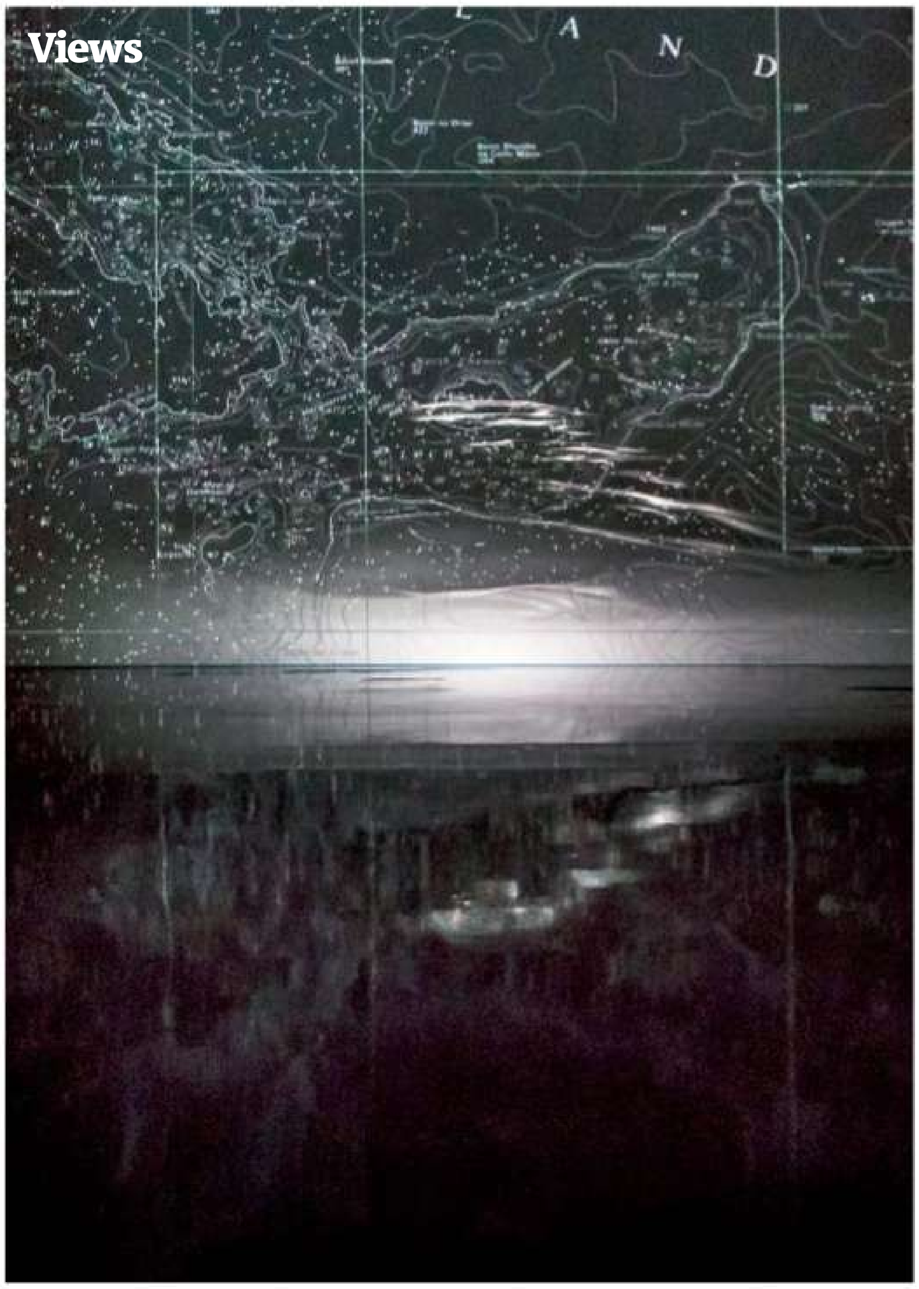
25 Comment
A new use for existing tech can help us tap deep geothermal energy, says Eugene Linden

28 The columnist
Graham Lawton on Chile's green constitution

30 Aperture
A close-up view of the unwanted guests of ants

33 Letters
Diving deeper into blue spaces

36 Culture columnist
Bethan Ackerley watches a harrowing hospital drama



SARAH DARLING

34 Whale strandings A new art exhibition explores strange whale deaths

Features

38 Silent therapy
How the right kind of quiet can benefit your body and mind

42 Fantastic figures
The unfathomable numbers revealing the universe's greatest secrets

46 Infant Earth
The quest for our planet's first dry land reveals clues to life's origins

The back pages

51 Stargazing at home
Spot the Teapot with the Milky Way steaming from its spout

53 Puzzles
Try our crossword, quick quiz and logic puzzle

54 *Almost* the last word
Does an electric car weigh more after being charged?

55 Tom Gauld for *New Scientist*
A cartoonist's take on the world

56 Feedback
A mummy in the attic and jellyfish crisps: the week in weird

Elsewhere on New Scientist

NS Live

Future stage

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Podcast

Weekly

The team talk to legendary writer Neil Gaiman about Netflix's new series *The Sandman*, based on his smash-hit comics. They also chew over the news that DeepMind's artificial intelligence AlphaFold has predicted the structure of nearly all proteins known to science, and explain how transformative this could be in areas such as disease prevention. Plus, there is more exciting news from the James Webb Space Telescope, which may have discovered a galaxy formed not long after the universe itself.

newscientist.com/nspod

LIAM DANIEL/NETFLIX

The Sandman Neil Gaiman on taking inspiration from science

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Cheating death A life extending technique to aid organ transplants

Video

Tangle teaser

Researchers at the University of California, Berkley, have developed a robot that can untangle long, knotted cables. The technology could be used to fit electrical cables in aircraft, or it might offer household assistance to older people, if only it can overcome one problem: the robot struggles if it drops one of its wires because it can't bend down to pick it up again.

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Newsletter

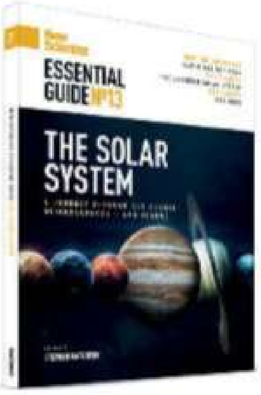
Health Check

Reporter Clare Wilson discusses a radical new technique to allow more organ transplants – one that could even redefine death. The method stops cells dying from lack of oxygen, but when trialled in pigs it also rejuvenated brain cells hours after the animal had died. Could it ever be used to bring humans back to life?

newscientist.com/ health-check

Newsletter

> "Perhaps in future we will only call someone dead if they have been dead for at least an hour"



Essential guide

How does the sun work? Why does the moon matter? Is there alien life? Knowledge of our solar system has reached new heights – but there is still much to discover about our nearest planets and the worlds beyond. Explore more in the latest *New Scientist Essential Guide*.

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BUILDING ON A MILLENNIUM OF ARAB INNOVATION

The Middle East was once at the forefront of invention. Algebra, universities, inoculation against disease, coffee, windmills, the arch and even the three-course meal: all had their genesis in the region. Yet over the past 150 years, the focus on innovation on a global scale has not been as sharp as it once was.

That's why, as we enter the second quarter of the Digital Century, the Kingdom of Saudi Arabia will reinvigorate that inventive tradition with a range of new research, development and innovation priorities aimed at addressing the most pressing issues affecting mankind today.

Through a focus on Health and Wellness, Sustainable Environment and Supply of Essential Needs, Energy and Industrial Leadership, and Economies of the Future, the newly established Research, Development and Innovation Authority (RDIA) will be a steward for the Kingdom's work with global partners, deploying a multi-billion-dollar budget over the coming years.

We are determined to help make world-class healthcare accessible and equitable across society. As an existing leader in digital health, the Kingdom will continue investing to advance the technology even further. As we demonstrated during the Covid-19 pandemic, this is an area in which we lead the world.

Saudi Arabia is intent on addressing not only domestic but also global health challenges through focusing on ultra-early disease detection and biotechnology to prevent the blight of illnesses such as cancer and chronic heart disease from ending lives prematurely.

A good life isn't limited to good health. Security of food, water and energy are vital for happiness and wellbeing.

The world's largest solar-powered desalination plant is located in Al Khafji in Saudi Arabia and we continue to invest in innovation to make desalination environmentally friendly, more accessible to many more households and businesses, cheaper to achieve and, crucially for food security, able to be used easily in farming.

Saudi Arabia has prospered over the past century thanks, in large part, to our oil revenue. We're now investing that revenue in finding cleaner, greener sources of energy to power our way into a brighter future. The Kingdom is building what will be the world's largest green hydrogen facility, with a production target of 50 tonnes a day, aiming to produce 5 million tonnes of clean hydrogen by 2030.

Though the innovation and invention timescale can be frustratingly long, the Kingdom is committed to becoming an innovation superpower in the next two decades. We expect that by 2040, our total expenditure on innovation will reach 2.5% of GDP, more than the G20 average.

We can't do this alone.

At the heart of our commitment to innovation is the desire to build globally collaborative schemes and institutions which, together, will help mankind harness technology to improve lives. Saudi Arabia will invest in bringing scientific talent from other nations to work with our own brightest minds.

KACST (the King Abdulaziz City for Science and Technology) – the Kingdom's leading research and innovation centre – is already working with Cambridge University, Harvard, Berkley and MIT to pool knowledge, resources, information, and ability. As our programme expands in capability, so will our world advance in possibility.

Innovation, investment and people: the Research, Development and Innovation Authority brings all these together. Building on 1,500 years of our region's exceptionally inventive history, the Kingdom of Saudi Arabia will use the fruits of our prosperity to build a better future for everyone, everywhere.

His Excellency Munir Eldesouki - President of King Abdul Aziz City for Science and Technology (KACST)

Advertisement

Running dry

Even rainy nations like the UK must act now to protect against future droughts

TEMPORARY bans on using hosepipes to fill up paddling pools might seem like a parochial issue. But such modest efforts as most of England nears drought are a reminder that even countries perceived as perpetually rainy will need to get serious about saving water in a warming world.

Drought is part of many countries' natural weather cycles, including the UK. But dry conditions are also expected to become more frequent and intense as Earth moves beyond the 1.2°C of climate change we have seen to date.

The worst is yet to come, which is bad news given how nations are faring today. Almost half of the European Union is in drought-warning conditions. France is experiencing its severest drought in history, with forecasts of corn harvests being down by almost a fifth and nuclear power output curbed by warm, low rivers. Half of the US is in drought too.

This scarcity of water adds to the pressure on the existing global food and energy crises, both linked in part to Russia's invasion of Ukraine. Drought can also lead to more climate change by stressing and ultimately killing forests that act as vital carbon stores.

> "This dry period needs to bite hard now, so we are ready for the future"

So what to do? Start taking this vital resource seriously, rather than for granted. That will require behaviour changes as well as technological fixes.

Mandatory water efficiency labels to help people pick better products like toilets and washing machines would be a start: the UK is readying these now. Household water meters are a must. UK water firms' goal of halving pipe leaks by 2050 isn't good enough. We need other big water infrastructure projects too, and we need to start now because they take time. A huge reservoir being built in the south of England won't be ready until 2028. Better planning is needed: it is inexcusable that the UK's only major desalination plant is currently offline.

As Christine Colvin at The Rivers Trust in the UK puts it: "This dry period needs to bite hard now, so we are ready for the future." Inaction will result in worse than tears over empty pools. ▮

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Long covid
1 in 8 infected people had persistent symptoms **p9**

Age in the blood
Transfusions from old to young mice hasten ageing **p11**

Gamma ray bursts
Bright explosions help measure cosmic expansion **p12**

Turtle wipeout
Early humans may have driven many species extinct **p13**

Bacterial immunity
Virus-resistant *E. coli* could be used to produce drugs **p15**

BILL CLARK/CQ-ROLL CALL, INC VIA GETTY IMAGES

Senator Ed Markey and activists celebrate the passage of the bill

Climate change

US steps up climate action

The US Senate has passed the Inflation Reduction Act, featuring the largest climate package in US history, reports **James Dinneen**

FROM what appeared to be stalled negotiations just two weeks ago, the US Senate has now passed the largest climate spending package in US history as part of a bill called the Inflation Reduction Act of 2022. As *New Scientist* went to press, the House was set to pass the legislation by the end of the week to later become law with President Joe Biden's signature.

The act aims to address inflation through policies to reduce the cost of energy as well as the federal deficit. It is expected to raise an estimated $790 billion in total, $369 billion of which is marked for energy and climate priorities.

The act will reduce US greenhouse gas emissions by electrifying things that currently run on fossil fuels and by generating more electricity using renewable and clean energy.

On the electrification side, the bill includes a $4000 tax credit for used electric vehicles and a $7500 credit for new electric vehicles, as well as tax credits for low-carbon renovations to homes, such as installing heat pumps and rooftop solar panels. It also puts $6 billion towards reducing emissions from hard-to-decarbonise industries like cement, chemical and steel plants. The US Postal Service – the largest source of federal emissions – gets $3 billion to buy zero-emission vehicles.

On the electricity generation side, the bill contains $30 billion in grants and establishes tax credits for states and electric utilities to adopt clean energy and energy storage, which is key for the stability of the grid with higher levels of intermittent renewable sources. This includes support for hydrogen and carbon capture technology, as well as new tax credits to keep nuclear power plants running. And it includes $60 billion to support clean energy manufacturing intended to accelerate production of solar panels, wind turbines, electric vehicles and heat pumps.

$369bn

The amount of money marked for climate priorities in the new bill

An analysis from Rhodium Group, an independent energy think tank, estimates the bill would reduce US greenhouse gas emissions by 31 to 44 per cent below 2005 levels by 2030, compared with a projected 24 to 35 per cent reduction without the bill. The expected reductions still fall short of the Biden administration's target of a 50 per cent reduction by 2030.

While praising the bill's spending on climate priorities, environmental groups have critisised its support for new fossil fuel development.

One provision in the bill says approval for renewable energy development on federal lands is contingent on auctioning oil and gas leases. The bill also requires the Department of the Interior to sell leases for oil and gas drilling in the Gulf of Mexico and off the coast of Alaska. "The bill is a hostage situation," says Jean Su at the Center for Biological Diversity, a US environmental advocacy group. "There are great renewable energy investments in this bill, but at the same time there are awful fossil fuel giveaways."

The draft bill was negotiated in secret by Senator Joe Manchin of West Virginia and Senate Majority Leader Chuck Schumer of New York. Manchin had said he would not support similar legislation, but in a surprise announcement on 27 July he revealed that the senators had reached a deal.

Manchin's support was contingent on the passage of a separate bill meant to speed up the permitting process for new energy projects, including a natural gas pipeline in West Virginia. Speedier permitting could be a boon for renewable energy projects, but Su says it could also help fossil fuel projects. ▮

Archaeology

Ancient bronze recipe deciphered

Mystery ingredients mentioned in an ancient Chinese text were probably pre-made alloys

Jason Arunn Murugesu

THE missing ingredients of an ancient Chinese recipe for bronze may have been uncovered, revealing another level of sophistication in the practice of chemistry at the time.

Kaogong Ji, a 2300-year-old text, is the oldest technical encyclopedia in the world. The book contains instructions on how to make several objects, such as metal drums, chariots and weapons. It also contains six recipes for bronze that have long puzzled researchers.

While bronze-making wasn't unique to China at that time, Ruiliang Liu at the British Museum in London says the style and scale of the bronzes produced there was unrivalled.

"We asked ourselves, how can Asian and Chinese people manage to produce so many bronzes [at that time]," says Liu.

Bronze is typically made by combining copper and tin. The recipe mystery centres on two ingredients called *jin* and *xi* that researchers have been unable to identify. In modern Mandarin, *jin* means gold, but in antiquity it is believed to have referred to copper or a copper alloy. Meanwhile, *xi* has long been considered to refer to tin.

But chemical analyses of bronze vessels from that time period suggest that *jin* and *xi* can't simply be copper and tin.

Liu and his colleagues analysed previously compiled data on the chemical composition of knife-shaped Chinese coins produced in the same era as when the recipes were recorded. By teasing out the relationships between the metals present in the coins, the researchers suggest the objects were created using pre-made alloys.

Knife-shaped coins used in China around 400 BC, made from complex alloys

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They discovered that the higher the lead concentration in the coins, the lower the concentration of both copper and tin. The coins with the highest concentration of copper also had the highest concentration of tin. These findings suggest that lead was being mixed into an alloy of copper and tin – a bronze alloy.

By modelling different combinations, the team determined that an 80:15:5 copper-tin-lead alloy mixed with a 50:50 copper-lead alloy in various ratios was the best match with the chemical coin data (*Antiquity*, DOI: 10.15184/aqy.2022.81).

These pre-made alloys are likely to be *jin* and *xi* respectively as recorded in the *Kaogong Ji*, says Liu. But he adds that the recipes in the book may not reflect how bronze was usually made.

"If anything, the recipes are too specific," he says. "The people who actually got their hands dirty probably couldn't read or write so they wouldn't have been able to record the recipe. I think there is a gap in knowledge between the person who wrote the recipe and the person who did the real work."

Bronze was used in ancient China to make large vessels for religious purposes, says Jessica Rawson at the University of Oxford. "In China, they had a huge workforce and so could afford to use a very complicated system with a lot more metal than in the West," she says. ▮

Neurotechnology

Artificial neuron swaps dopamine with rat brain cells

AN ARTIFICIAL neuron that can both release and receive dopamine in connection with real rat cells could be used in future machine-human interfaces.

Most brain-machine interfaces measure simple electrical signals in neurons to glean information about brain function. But much of the information in neural networks like the brain is encoded in neurotransmitters such as dopamine, chemicals that neurons use to send messages to each other.

"The brain's native language is chemical, but current brain-machine interfaces all use an electrical language," says Benhui Hu at Nanjing Medical University in China. "So we devised an artificial neuron to duplicate the way a real neuron communicates."

The neuron consists of a sensor made from a graphene and carbon nanotube electrode, which can detect when dopamine is released. If enough of it is detected by the sensor, a component called a memristor triggers the release of more dopamine at the other end through a heat-activated hydrogel.

Hu and his team demonstrated that the neuron is able to both send and receive dopamine in communication with rat brain cells in a dish. It could also activate a mouse muscle through the sciatic nerve and move a robotic hand (*Nature Electronics*, doi.org/h7mf).

The artificial neuron's memristor can change how much dopamine is required to trigger it to release the chemical. This is similar to how neurons in the brain change how much neurotransmitter is sent between connections in response to external stimuli, a trait called plasticity that is essential for learning.

"The brain's native language is chemical, but current interfaces all use an electrical language"

"This actually has quite a lot of potential for expanding into more sophisticated learning systems. You can do a lot of new cool things here," says Yoeri van de Burgt at Eindhoven University of Technology in the Netherlands. ▮

Alex Wilkins

Coronavirus

Long covid struck 1 in 8 adults who got infected

Jason Arunn Murugesu

AROUND 1 in 8 adults who had a covid-19 infection during the early stages of the pandemic developed long covid symptoms, according to a survey in the Netherlands.

Long covid is defined by the World Health Organization as an illness that usually occurs within three months from the onset of covid-19, with symptoms that last for at least two months. These can't be explained by an alternative diagnosis and can include chest pain, loss of smell and painful muscles. The symptoms have many causes, so it is hard to determine how many people experience these long-term effects as a result of covid-19 infection.

Aranka Ballering at the University of Groningen and her colleagues surveyed more than 76,000 adults in Drenthe, Friesland and Groningen in the north of the Netherlands between 31 March 2020 and 2 August 2021. The participants were surveyed weekly at first and less frequently as the study went on.

During the study period, 4251 people were diagnosed with covid-19 for the first time. The team matched each of these people to two others of the same age and sex who weren't infected at the same time.

By comparing the people who had covid-19 with the matched controls on the same dates, the researchers could better determine which symptoms were caused by long covid.

They defined long covid as a condition in which at least one symptom increased to moderate severity three to five months after a person developed covid-19. According to these criteria, about 1 in 8 people in the study who got covid-19 developed long covid. Loss of smell and taste, painful muscles and general tiredness were the most prevalent long covid symptoms (*The Lancet*, doi.org/gqmb5v).

The team also found that it took longer for long covid symptom severity to return to baseline levels in women compared with men. Some studies suggest that women face greater barriers to healthcare and so seek out help for symptoms later, and this may affect the severity of long covid, says Ballering.

The ancestral and alpha SARS-CoV-2 variants were most prevalent during the study period, so the findings may not extend to people infected with other variants. The study also doesn't show what effect vaccines may have had on long covid. Just 10 per cent of the participants had been fully vaccinated by the end of the study.

12.7%

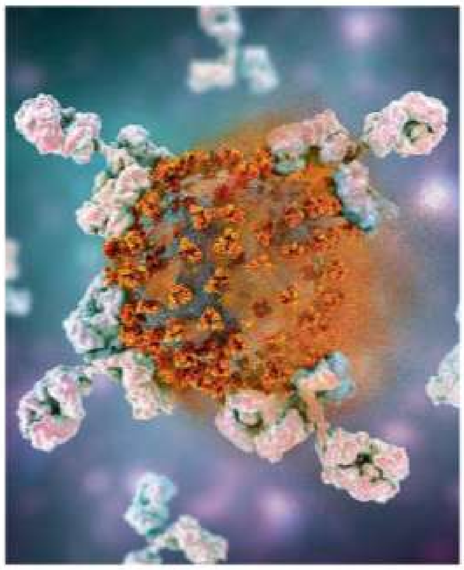
Proportion of people with covid-19 who got long covid

About 98 per cent of those studied were white and they were all in the Netherlands, so these results may not extend to other ethnic and national groups. It is also unclear how long covid risk changes when people are infected with the virus multiple times, says Ballering.

"I think these figures are an underestimate," says Danny Altmann at Imperial College London. "What I can say from my research is that I think we're undercounting long covid, not overcounting it." ▮

Immune system

Other coronaviruses shape covid-19 response



KATERYNA KON/SCIENCE PHOTO LIBRARY

An illustration of antibodies responding to SARS-CoV-2

PEOPLE with a stronger immune response to the coronaviruses that cause common cold-like symptoms may be better protected against covid-19.

Ricardo da Silva Antunes at La Jolla Institute for Immunology in California and his colleagues analysed blood samples collected from 32 people between 2016 and 2019, before covid-19 emerged.

Multiple samples were taken over six months to three years. The team wanted to see how the immune cells in these samples responded to four coronaviruses that cause common cold-like symptoms as well as the original SARS-CoV-2 virus.

SARS-CoV-2 has similar genetic sequences to the four cold-like coronaviruses, says da Silva Antunes. Earlier work also suggests stronger T-cell responses induced by prior coronaviruses may protect against SARS-CoV-2.

In the latest study, the researchers combined the participants' blood with peptides – strings of amino acids – from the different cold-like coronaviruses. Immune responses are typically triggered by the body recognising viral peptides. Next, they measured the T-cell and antibody responses in the blood when exposed to these viruses.

Looking at multiple samples from each participant, the researchers found the T-cell and antibody responses were stable for all four cold-like coronaviruses.

By looking at the T-cells, some of which are more likely to be activated by recent re-infections, they determined these immune responses weren't due to regular re-infections. Instead, this immune response may be relatively stable.

Da Silva Antunes speculates that if cold-like coronaviruses elicit similar immune responses, it may generate an immune memory.

In the second part of the experiment, the researchers combined the participants' blood with SARS-CoV-2. They found that those with the strongest T-cell immune response to the cold-like coronaviruses had the strongest response to SARS-CoV-2. The same wasn't found for antibody levels.

But the participants with stronger responses against cold-like coronaviruses weren't necessarily less likely to have severe covid-19, says da Silva Antunes (*Cell Host & Microbe*, doi.org/gqjjbk). Assuming most people have been exposed to cold-like coronaviruses, it isn't clear why some become ill with covid-19.

Overall, similar findings are expected with newer SARS-CoV-2 variants as the mutations don't affect the T-cell response much, says da Silva Antunes. Mala Maini at University College London says the study suggests T-cell immunity to cold-like coronaviruses shapes our SARS-CoV-2 response. Her team is working on a pan-coronavirus vaccine that targets a genetic sequence shared by SARS-CoV-2 and cold-like coronaviruses. ▮ **JAM**

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Briefing

How cryptocurrencies get hacked

Digital currencies are designed to be "unhackable", but that doesn't mean funds are safe from criminals, says **Matthew Sparkes**

BIG cryptocurrency heists are raising concerns about whether digital currencies are safe to invest in. It emerged last week that US cryptocurrency firm Nomad has been hit by a $190 million hack, and trading service ZB Exchange has paused withdrawals after a suspected $5 million loss to hackers. A similar amount was stolen from Solana wallets and, just two months ago, a group thought to be based in North Korea is believed to have siphoned off $100 million in various cryptocurrencies. So just how safe are bitcoin and other cryptocurrencies?

How do cryptocurrencies work?

Cryptocurrencies are essentially digital currencies that operate free of central control or the oversight of banks or governments. Instead, they rely on peer-to-peer software and various types of cryptography.

Are cryptocurrencies hackable?

There is a lot of variation in the workings of different cryptocurrencies, but the cryptography behind many coins – including bitcoin – is based on the SHA-256 algorithm designed by the US National Security Agency. Cracking this to steal currency is all but impossible, even for quantum computers.

The vulnerability to hacking tends to lie in the infrastructure around cryptocurrencies. These digital assets can be stored in two main ways: in wallets that you control personally or in exchanges that act a little like banks. The former means that you are in control, so your security is as strong or weak as you make it. The fundamental technology that runs the currency is strong, but if your computer is hacked you could still lose your funds. What's more, a broken hard disc or a house fire could also see you permanently out of pocket.

An ATM for various cryptocurrencies in Hong Kong

PAUL YEUNG/BLOOMBERG VIA GETTY IMAGES

Can "lost" coins ever be recovered?

If your cryptocurrency is stolen, technological and legislative hurdles may prevent police forces getting very far in any investigation. As of the start of this year, UK police forces had seized a combined £300 million in cryptocurrencies – a not inconsiderable sum, but probably only a tiny fraction of the funds being used in the UK for illegal purposes. Because of the murky and international world of hacking, lost funds are unlikely to be tracked down and even less likely to be recoverable.

Is regulation needed?

Nigel Green, chief executive of financial services firm deVere Group, says more regulation is necessary to protect customers and exchanges need to be held to the same standards that traditional banks are.

"Nearly all foreign exchange transactions go through banks or currency houses, and this is what needs to happen with cryptocurrencies," he says. "[When funds flow] through regulated exchanges, it will be much easier to tackle potential wrongdoing, such as money laundering, and make sure tax is paid." ▮

Ageing

Young mice age when given blood from older animals

TRANSFUSING young mice with blood from older rodents triggers cellular ageing, suggesting ageing isn't all down to wear and tear.

According to current thinking, surgically connecting an old mouse with a young rodent causes a transfer of blood that de-ages the older animal. While this benefits the older mouse, the effects on the young donor rodent were less clear.

To learn more, Irina Conboy at the University of California, Berkeley, and her team transfused blood between young mice, aged 3 months, and old mice, which were nearly 2 years old.

Two weeks later, the young mice had an increased number of senescent cells, ones that are damaged and stop dividing but don't die. These cells accumulate as a normal part of ageing, beginning after a few years of life in humans.

Strength tests also revealed the young mice became weaker after receiving the older rodents' blood (*Nature Metabolism*, doi.org/h7jv).

Overall, the results suggest that senescent cells can be induced in young animals outside of chronological ageing. "Cell senescence is only part of the process of ageing," says Conboy. "That opens new horizons and helps explain why senolytics [drugs that clear senescent cells in the body] so far in clinical trials were less successful than people hoped."

Nevertheless, senescent cells didn't develop in young mice when the old mice were treated with senolytics before a blood exchange.

"Strength tests revealed the young mice became weaker after receiving the older rodents' blood"

"This is a very exciting study that highlights a potential anti-ageing treatment," says Roman Bauer at the University of Surrey in the UK.

Bauer says previous research suggests that clearing senescent cells from mice rejuvenates their blood. Referring to the Berkeley study, he says: "The research also demonstrates opportunities for senolytics, so drugs that eliminate senescent cells, which we are currently also investigating for cancer treatment." ▮

Chris Stokel-Walker

Genetics

Dog disease mutation edited out

CRISPR editing could prevent a common genetic condition in Labradors

Michael Le Page

TWO Labrador dogs called Gene and Geny have been born in South Korea after CRISPR gene editing was used to correct a mutation linked to a common hip condition. It is the first time gene editing has been used to attempt to prevent a genetic disorder in dogs, but it won't be clear how successful it has been until the animals are older.

"The study was performed to develop a procedure for getting rid of harmful mutations from pets," says team member Okjae Koo at biotech company ToolGen. "We believe that Gene and Geny will prove that the correction of harmful mutations by genome editing can cure the diseases of both pets and humans."

Many pets, especially inbred pedigree ones, have high levels of disease-causing mutations, some associated with features breeders select for. One common unwanted condition in dogs is hip dysplasia, caused by the hip joint failing to form properly, resulting in pain and difficulty moving as the joint wears out earlier than normal.

MKBIOTECH/CHUNGNAM NATIONAL UNIVERSITY

Gene and Geny, the gene-edited, cloned Labrador puppies

Hip dysplasia is hereditary. However, factors such as exercise and obesity help determine at what age dogs are affected and how severe the problem is. The condition is particularly common in Labradors.

The team, led by Min Kyu Kim at Chungnam National University in South Korea, has previously identified a number of mutations associated with hip dysplasia in dogs. To try to create dogs that are free of the condition, the researchers first took skin cells from the ear of a Labrador with hip dysplasia.

Next, they used a variant of CRISPR gene editing called prime editing to correct one mutation linked to hip dysplasia in the skin cells. The corrected cells were then fused with eggs whose DNA had been removed, to create cloned embryos that were implanted in a surrogate mother.

Gene and Geny are therefore clones of the dog from which the skin cells were taken, but with the mutation corrected. However, it might prove necessary to correct several mutations, not just one, to ensure dogs don't develop hip dysplasia, the team warns.

The standard form of CRISPR can induce unwanted mutations along with the intended change, but prime editing is more precise. The team didn't find any unwanted mutations in Gene and Geny (*Scientific Reports*, doi.org/h7br).

But because of the method used to select corrected cells, the dogs do have some added genes, including one for the fluorescent green protein GFP, meaning they glow green under UV light.

In some countries, including the UK, there are screening programmes intended to reduce the incidence of hip dysplasia in dogs.

"Many pets, especially inbred pedigree ones, have high levels of disease-causing mutations"

"Gene editing may offer an alternative to tackling the issue, but this experimental approach still comes with a lot of unknowns, particularly around its unintended consequences, but also the longer-term impacts of intended changes," says Justine Shotton, president of the British Veterinary Association. ▮

Space

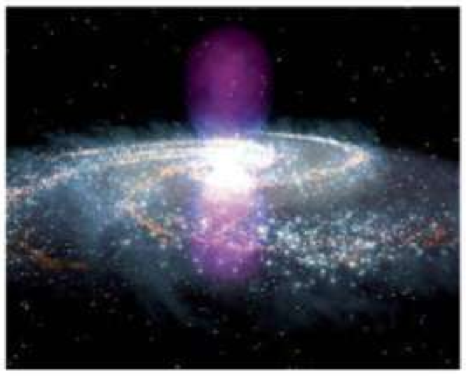
Gamma ray bursts could unpack universe expansion

BLASTS of gamma rays from the distant universe may provide a new way to measure cosmic distances – and help us understand the structure and expansion of the universe.

The brightest events in the universe, gamma ray bursts (GRBs) can occur when huge stars die in supernova explosions, producing powerful flashes of radiation.

Maria Giovanna Dainotti at the National Astronomical Observatory of Japan and her colleagues examined observations of 500 GRBs, looking for common features in visible wavelengths of light that could tie some of these strange events together. They found that 179 of the GRBs in their sample exhibited an afterglow after the main explosion, probably caused by fast-spinning newborn neutron stars, with predictable properties.

By standardising the light – finding similarities in many of these GRBs and working out where they come from and what other properties of the GRBs they are related to – the researchers can turn these GRBs into so-called standard candles (*The Astrophysical Journal Supplement Series*, doi.org/gqjjd3).


NASA/GODDARD SPACE FLIGHT CENTER

Gamma ray bursts are the brightest events in the universe

A standard candle is an object with a known brightness. By comparing this actual brightness with how bright the object seems from Earth, we can use it to measure distances. For extremely distant objects, this is the only way to tell how far away they are.

This is crucial because we need to understand precisely how far away the most distant galaxies are in order to calculate how fast the universe is expanding, which is represented by a number called the Hubble constant. Researchers have been arguing over this number for decades, and new standard candles could help sort out its true value. GRBs could be a step in the right direction but we need to find more of them before they can really make a dent in the debate, says Dainotti. ▮

Leah Crane

Palaeontology

Early humans killed off turtle species millions of years ago

Michael Le Page

OUR ancestors may have been wiping out other species long before modern humans evolved, suggests a new analysis.

"Our finding… highlights how far back in time a negative hominin influence on biodiversity extends," write Anieli Pereira, formerly at the University of Gothenburg in Sweden, and her colleagues.

Modern humans have had a massive effect on ecosystems from at least 125,000 years ago, wiping out big animals. But many suspect the impact began much earlier.

Tortoises and other turtles may have been especially vulnerable, because their defence mechanism of retracting into their shell fails against intelligent aggressors.

Pereira and her colleagues looked at about 3400 fossils, representing 82 living and 908 extinct species, to see how extinction rates changed. There were three major extinction events: two were ancient, with one coinciding with the extinction of the dinosaurs. The third began some 5 million years ago and hasn't ended.

The extinction rates rose only in turtles that lived mostly on land, not in aquatic species. What's more, extinction rates in the Americas and Australia – which humans reached later – went up only about a million years ago, much later than in Africa and Asia (bioRxiv, doi.org/h7ch).

"Our results point towards a hominin cause of extinctions rather than global climate change," the team concludes.

However, Nick Longrich at the University of Bath, UK, points out that humans reached Australia only around 70,000 years ago and the Americas around 35,000 years ago.

This discrepancy could be caused by the fact that many recent fossils are dated only as being from the Pleistocene, an epoch that lasted from 2.6 million to 12,000 years ago, the researchers note. More accurate dating might clarify this. ▮

Environment

How to shop for eco-friendly food in the supermarket

Adam Vaughan

TOLGA AKMEN/AFP VIA GETTY IMAGES

AVOID the supermarket aisles piled with cheese, quiches and pies. That is the message of an analysis that found these items fare worst when looking at both nutritional and environmental impacts of thousands of food and drink products sold in the UK and Ireland. And if your priority is curbing carbon emissions and water use, avoid the meat and fish shelves too.

So far, most studies assessing the environmental footprint of food have focused on the impact of commodities such as beef or soya, rather than the lasagnes, tofu and other products that shoppers often buy. Where research has focused on such products, it has usually been for a small number of them.

In a bid to bridge the gap, Michael Clark at the University of Oxford and his colleagues analysed more than 57,000 food and drink products sold in the UK and Ireland. The team took the ingredients data from eight retailers, including major supermarkets Tesco and Sainsbury's.

However, precise figures on how much of each ingredient is in each product were only available for around a tenth of them. To estimate the rest, Clark and his colleagues trained an algorithm on the known products and used it to predict the composition of the unknown ones, helped by the fact that regulations in the UK and Ireland mean ingredients must be listed in descending order of quantity. Finally, the team linked all the ingredients to an existing database of environmental impacts, including emissions, land use and water stress.

57,000

Number of products from supermarkets analysed in study

The results may come as no surprise: meat, fish and cheese products had the highest environmental impact. Desserts, pastries and savoury pies came next. Fruit, vegetables, bread and sugary beverages had the lowest burden. For the most part, there was an overlap between low environmental impact and good nutrition, a further analysis showed (*PNAS*, doi.org/h7md).

Food stores struggle with eco labelling

Clark concedes that none of this is mind-blowing, given what we already knew from past research. "The major advance is not that beef has high impacts, fish has high impacts, cheese has high impacts. It's the fact that you can start getting these impact estimates for products that people are purchasing, which then has a lot of knock-on implications," he says.

One of those is eco-labels, which a growing body of evidence shows can steer consumers to make greener choices. However, retailers have struggled in the past with the scale of the challenge. In 2012, Tesco stopped trying to add carbon footprint labels to all its products because it would take centuries to assess them at the rate it was managing.

Clark's approach points the way to doing such labelling at scale. He is thinking about how to eventually turn the data into an app that could be used either by shoppers or by retailers wanting to reduce their environmental impact. "We've made that information available in a way that means people can start making informed decisions," he says.

A limitation of the research is that it doesn't account for different sources of the same ingredients, such as beef produced in the UK or imported. For example, according to the UK Climate Change Committee, UK beef emissions are 14 per cent lower than the European Union average. ▮

Space

JWST spots cosmic cartwheel...

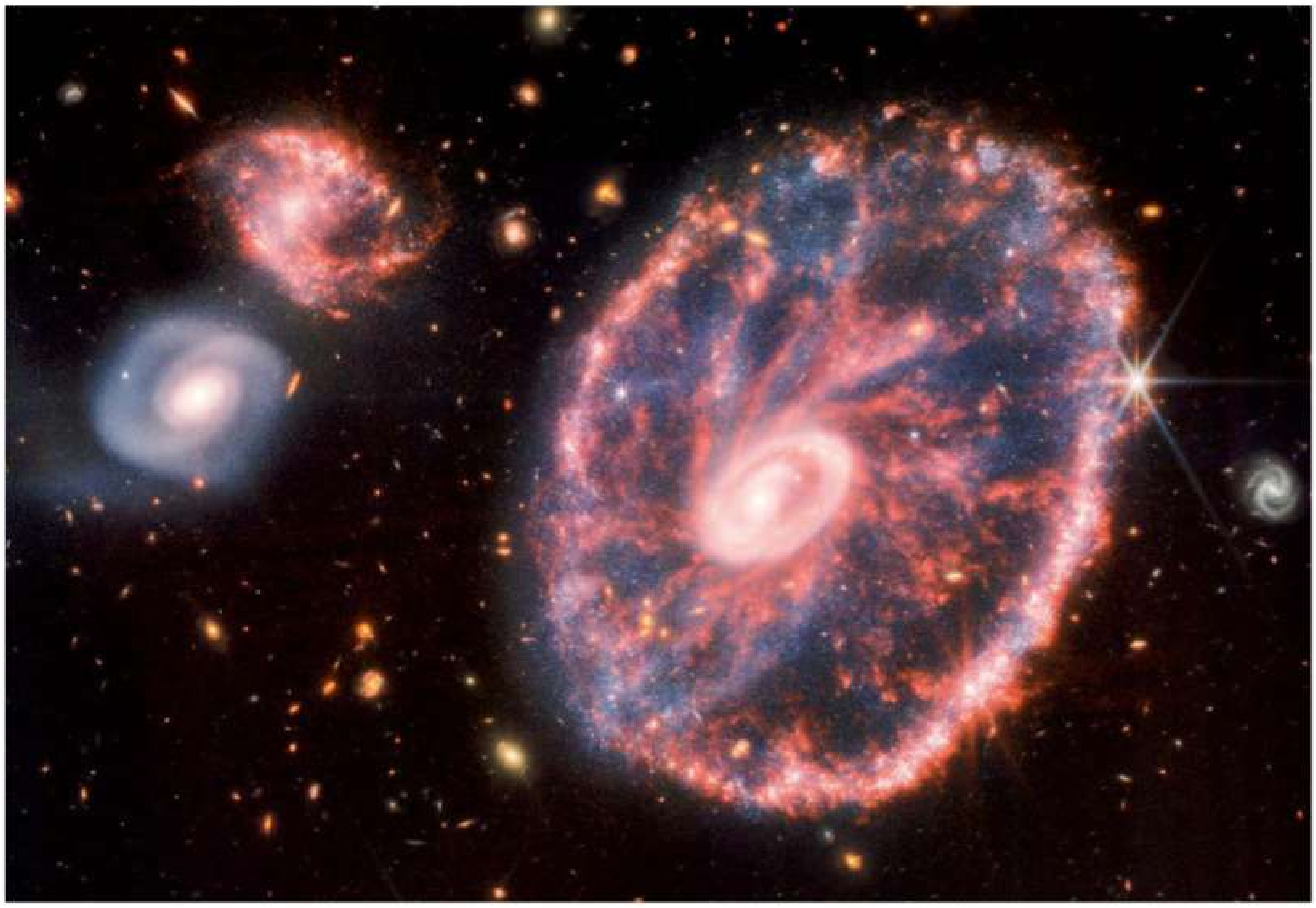
Stunning galaxy has ripples made of stars and gas

Leah Crane

ONE of the strangest galaxies in the universe has been captured by the James Webb Space Telescope. The details of the Cartwheel galaxy are obscured by dust, but the new images peer through to reveal it in more detail than ever before.

The Cartwheel galaxy is about 500 million light years away and measures about 150,000 light years across. Researchers believe that it was a spiral galaxy similar to the Milky Way before one of its companion galaxies crashed through, sending waves of stars and gas rippling out from the centre, creating its nested ring shapes.

The inner ring is made mostly of hot, bright dust, along with some huge clusters of young stars. The outer ring is just as dynamic if not even more so – as it expands outward, it smashes through the gas surrounding the galaxy and triggers bursts of star formation, which light up the surrounding dust.



NASA, ESA, CSA, STSCI, WEBB ERO PRODUCTION TEAM

...and two galaxies smashing together

THE James Webb Space Telescope (JWST) has also caught two galaxies colliding. In the midst of this cosmic clash, researchers have found something unexpected – there doesn't seem to be an active supermassive black hole in either galaxy.

The pair of galaxies, called IC 1623 or VV 114, is about 275 million light years away in the direction of the constellation Cetus. Lee Armus at the California Institute of Technology and his colleagues observed them with JWST as part of a campaign to spot four relatively nearby, bright galaxy mergers and figure out how they work.

"A merger brings dramatic changes to the galaxy's shape and content and pretty much everything, so we really have to understand this process to figure out how galaxies evolve," says Vivian U at the University of California, Irvine, part of the team conducting this research.

As two galaxies orbit one another and collide, they rip huge streams of material off one another and create massive shock waves that pass through both galaxies. Both of these processes are occurring in the red splotches in this image, right, which are star-forming regions shrouded in dust. They were most likely spurred into activity by the shock waves.

Nearly every massive galaxy has a supermassive black hole at its centre, and researchers expect the black holes in merging galaxies to be relatively active, devouring gas from their surroundings and emitting huge amounts of radiation in the process. But when U and her colleagues began analysing the data from IC 1623, they found no sign of active black holes.

IC 1623 is a pair of galaxies 275 million light years away

NASA/ESA/CSA/STSCI/R. COLOMBARI

"These mergers typically rile things up and cause these black holes to get a lot of gas and then they're excited and things get interesting, but we don't see that here," says Armus. "It may be that we have to look a little harder – they don't always stand up and wave." A supermassive black hole or two may simply be unexpectedly inactive or hidden deep within the colliding galaxies.

Leah Crane

Technology

Earphone can 'hear' commands user is silently mouthing

Jeremy Hsu

PEOPLE could soon let their ears do the talking when using a virtual assistant thanks to a device that detects changes in the shape of the ear canal when silently mouthing commands.

"One key problem for using voice assistants right now is that every time [we use them], we need to say some activation words, so this will feel very awkward in the public scenarios," says Zhanpeng Jin at the University at Buffalo in New York. "You don't want to sit in public and say, 'hey Siri, go ahead and do something.'"

JUSTIN LAMBERT/GETTY IMAGES

Mouthing words could be enough to issue commands to a virtual assistant

Jin and his colleagues have now created the EarCommand system in an attempt to address this problem. It works by emitting near-ultrasound signals into the wearer's ear and detecting reflected echoes through an inward-facing speaker and microphone. An artificially intelligent algorithm analyses the reflections and learns to associate warping of the ear canal's shape with particular words, such as the names of popular smartphone apps like TikTok and Snapchat, and commands such as "what's the weather" and "call mom".

The system currently recognises 32 single-word commands and 25 sentence-length commands. It makes mistakes about 10 per cent of the time when recognising commands composed of single words and 12 per cent of the time when interpreting sentences (*Proceedings of the ACM*, doi.org/h7bj).

Microbes

Virus-resistant *E. coli* could be used in drug production

Michael Le Page

SOME viruses can infect and kill an engineered *Escherichia coli* bacterium that was supposedly resistant to all viral infections, but further changes have made the bacterium much more virus-resistant.

Many chemicals and drugs, such as insulin, are produced by growing genetically engineered *E. coli* in large vats. However, there is always a risk that bacteria-infecting viruses called bacteriophages can wreak havoc.

"If a single bacteriophage gets into these fermenters, in just hours, everything is dead," says Akos Nyerges at Harvard University.

To avoid this scenario, several groups are developing virus-resistant bacteria. Nyerges won't go so far as to say that his team's souped-up *E. coli* strain could never be infected, "but it's highly unlikely", he says.

Synthetic microbe

The ability of viruses to infect cells depends on the fact that all living organisms use the same genetic code, with only a few variations. The idea is to change this code.

DNA in cells contains recipes for making proteins, which are strings of amino acids. Three-letter bits of DNA, called codons, code for a specific amino acid or a "stop making this protein" signal.

In cells' protein-making factories, molecules called transfer RNAs, or tRNAs, recognise each codon and add the appropriate amino acid to the protein chain.

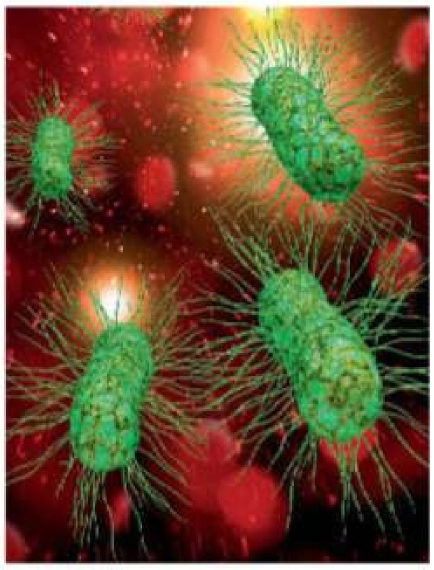
Overall, there are 20 amino acids and 64 codons, which makes for a lot of redundancy. For instance, there are six different codons that code for the amino acid serine.

In 2019, a team led by Jason Chin at the University of Cambridge resynthesised the DNA of an *E. coli* bacterium from scratch to change all instances of two serine codons to one of the other serine codons. The researchers did the same with one stop codon. This led to an *E. coli* strain they called Syn61, because it uses only 61 codons.

Syn61 wasn't virus resistant because tRNAs that recognise the eliminated codons are still present, meaning viral genes can still be translated into proteins. In an effort to overcome this, Chin and his team deleted these tRNAs. "The resulting strain provides complete resistance to a cocktail of viruses," they reported in 2021.

But when Chin's team made Syn61 available to other researchers, Nyerges and his colleagues, including George Church, exposed it to viruses from sources such as sewage, rivers and lakes. Twelve viruses were able to infect the strain.

***E. coli* is involved in the production of many chemicals and drugs**



EZUME IMAGES/SHUTTERSTOCK

This occurred because some viruses possess their own genes for tRNAs, which can compensate for the tRNAs deleted by Chin's approach.

To combat this, Nyerges and his team modified Syn61 so the two freed-up codons that coded for serine now code for the amino acid leucine (bioRxiv, doi.org/h7b4).

When viruses infect this modified strain, their proteins have leucine added in places where there should be serine, rendering the viral proteins useless and preventing replication.

64

The number of codons, which code for amino acids and "stop signals"

"Considering the myriad of viruses out there, I don't think it's surprising that they found some capable of infecting Syn61 – although I have to admit that, until this preprint, I didn't realise viruses had this mechanism to avoid the missing tRNA problem," says Tom Ellis at Imperial College London.

"I don't think we can ever say it's 100 per cent foolproof, but I think the approach used in this preprint is very, very, very unlikely to be something that viruses can find a way around," he says.

Nyerges's team also made the modified strain dependent on an artificial amino acid to prevent it from spreading outside of any laboratories or factories.

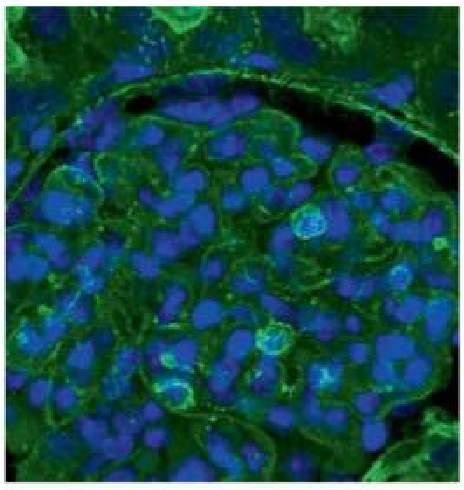
Chin didn't respond to questions from *New Scientist*.

Medicine

Organs kept alive after heart stops

An artificial blood substitute tested in pigs could make more organs available for transplants, and one day might even reverse death, reports **Clare Wilson**

JULIA LOTOTSKAYA/SHUTTERSTOCK



YALE SCHOOL OF MEDICINE

Kidney cells from pigs treated with OrganEx (above) show less damage than those put on a heart-lung machine

A PROCEDURE that reverses cell damage after the heart has stopped pumping blood may lead to more organ transplants and better treatments for heart attacks and strokes, and one day could even save the lives of people who would currently be considered dead.

The method, which so far has been tested on pigs, involves connecting an animal to a pump that perfuses their body with an artificial blood substitute containing oxygen and a mixture of other chemicals to prevent cell death and promote repair processes.

"We have shown that cells don't die as quickly as we assumed they do, which opens up possibilities for intervention. We can persuade cells not to die," says Zvonimir Vrselja at Yale School of Medicine.

Currently, people whose hearts are failing may be connected to heart-lung machines, which oxygenate their blood, remove carbon dioxide from it and pump it around the body.

> **"If it is successful in resuscitating an injured organ, then potentially this is very exciting"**

But if someone's heart stops while they are outside of a hospital, their cells and organs are quickly damaged by the lack of oxygen and their chances of survival plummet. Their blood becomes more acidic from a build-up of CO_2 and many damaging substances are released.

The new system, called OrganEx, dilutes the animal's blood in a 1-to-1 ratio with an artificial blood substitute that carries oxygen, has the correct acidity and has the right levels of electrolytes and other biochemicals.

It also contains 13 drugs, including compounds that thin the blood to stop small blood vessels getting blocked by clots, drugs that block a cell death process called necroptosis and others that have anti-inflammatory effects.

The blood substitute is also unusual in that it contains no red blood cells, which normally carry oxygen bound to a protein called haemoglobin. Instead, the fluid contains Hemopure, a form of haemoglobin obtained from cow's blood.

In 2019, Vrselja and his team reported that their system could reverse signs of cell death when connected to the brains of pigs, 4 hours after they had been decapitated. In the latest study, the team wanted to see if it could help reverse the damage that occurs in other organs after death, and to test it in whole bodies.

The pigs were put to sleep with a general anaesthetic and put on ventilators to control their breathing. Then their hearts were stopped electrically and the ventilators were turned off, at which point they would normally be considered dead.

After 1 hour, the treatments to try to restore cell function began. Six pigs were connected to the OrganEx system and six others were connected to an ordinary heart-lung machine as a comparison, with both groups' body temperature reduced to 28°C to help reduce damage. There were three further control groups, where the animals were given no treatment.

Stopping cell death

After 6 hours, the extent of blood flow was measured by injecting dye and doing scans of the animals. The pigs given the OrganEx treatment had better blood supply to their organs than the animals put on a heart-lung machine, in which many of the smaller blood vessels had collapsed.

Tests on cells and tissue samples from the animals showed that those treated with OrganEx had less cell death and had restored cell functioning, judged by measures such as how much glucose they could metabolise (*Nature*, doi.org/h664).

The team says the first practical use of the system may be in keeping organs for transplants healthy for longer so they can be transported further between deceased donors and people who need them.

Peter Friend at the University of Oxford says the initial results are promising, but the best way to gauge the health of the animals' organs would be to transplant them into another animal. "That lets you see if they work," he says.

The system could also potentially be used to help people who have had heart attacks or strokes – when blood supply to the heart or brain, respectively, is reduced – by perfusing either of these organs with the healing fluid. "If it is successful in resuscitating an organ which has suffered an otherwise fatal injury, then potentially this is very exciting," says Friend.

Stephen Latham, an ethicist at Yale University who was part of the research team, says the more radical use of trying to "reverse death" – for instance, in treating someone some time after their heart has stopped due to drowning – would be much further in the future. ■

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Diagnosed with autism spectrum disorder at the age of 8, Camilla has created her own manual for understanding humans, which won the Royal Society Insight Investment Science Book Prize in 2020. She is a champion for neurodiversity who recently published a book for children, revealing how as a child she used scientific ideas she understood to help explain social customs she didn't. Camilla believes all children should know it is completely normal to be perfectly weird. In fact, it is essential for growing up happy.

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Climate change

Alaska's record-breaking fires

Wildfires have torn through three times as much territory in the region than usual, and fire season isn't over. **Lois Parshley** looks at what this could mean for the Arctic

JAMES LILY/ALASKA DIVISION OF FORESTRY

The frequency of large wildfire seasons in Alaska has doubled in 30 years

LATE in the evening, Walton Smith sat on his front porch and watched the tundra burn. For weeks, a wildfire had been licking towards his home in St Mary's, a town of 600 people in western Alaska. As the sun sank, he could see flames jump between trees. Smith, who is St Mary's city manager, says that as the cones in the spruce flared, "all of the trees around it would suddenly be engulfed in flames".

The state has been ablaze since April, torching 12,400 square kilometres so far – more than three times what normally burns in a year. "In the last 30 years, the frequency of large wildfire seasons has doubled," says Rick Thoman at the University of Alaska Fairbanks. Climate change is increasingly priming the land to burn, he says, with repercussions that extend well beyond Alaska.

By far the largest US state, Alaska is nearly two-and-a-half times the size of Texas. It has many microclimates and ecosystems, from unbroken stretches of tundra to vast swathes of boreal forest, whose spruce and birch trees are crucial to many of the world's migrating bird species.

St Mary's sits inland on one of the Yukon river's tributaries, where warmer springs have driven shrub growth: alder and willows thicketing river bottoms and hillsides are ready fuel for fire. Unusually light snowfall before a dry spell left south-west Alaska parched. "The tundra actually crunched," Smith recalls. "It wasn't soggy and spongy the way it's supposed to be."

All it took to spark disaster was a lightning strike. Warmer air holds more moisture, which raises the risks of thunderstorms. Recently, strikes have increased where they were once rare. "In western and south-western Alaska, fire frequency has nowhere to go but up," says Thoman.

12,400

Area burned in Alaska so far this year, in square kilometres

50 years

How long it can take for lichen to recover after wildfire

10%

Chances of a summer in Fairbanks without smoke reducing visibility

Alaskan fires are also burning hotter and deeper. Wildfire is an important part of the boreal ecosystem – black spruce trees depend on the heat of wildfires to open their cones and release their seeds – but "if you change the frequency and intensity of fires, it has an effect across the whole landscape", says Nancy Fresco at the University of Alaska Fairbanks.

When the land's protective top layer is scorched, the permafrost can begin to thaw, destabilising the earth until it collapses into marshy hollows and hummocks, a process called thermokarst. In an analysis of 70 years of data from Alaska's Noatak National Preserve, Yaping Chen at the College of William & Mary, Virginia, and her colleagues found that thermokarst rates rapidly rise after wildfire. "The effect of fire can last for decades," she says.

Permafrost is the foundation of the Arctic landscape, so its thaw has a cascading effect. In poorly drained lowlands, water pools can absorb heat, which speeds soil warming, causing more thawing. Fire has a similar effect. "A charred landscape becomes darker and absorbs more heat," says Chen.

Permafrost also stores large amounts of organic matter and nutrients, says Bianca Rodríguez-Cardona at the University of Quebec in Canada. In a study of the Central Siberian plateau, she and her colleagues found that nitrate levels in streams increase for a decade after wildfire. This can cause algal blooms, which may harm fish by lowering oxygen levels. It can also lead to dramatic drops in dissolved organic carbon – a main food source for microbes at the bottom of the food chain – for the next 50 years.

That's to say nothing of the

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greenhouse gas emissions when permafrost thaws. Collectively, it holds about twice as much carbon as is now in the atmosphere, almost 1600 gigatonnes, but most climate models overlook fire-induced thaw emissions.

If these trends continue, "there's a threshold after which the ecosystem may never recover", says Chen. Many Arctic plants, like cranberries and blueberries, can survive burning above ground, but when severe fires scorch their root masses, it forces them to reseed from elsewhere and slows regrowth, says Jennifer Barnes, a fire ecologist at the US National Park Service in Alaska. Spruce take decades to grow cones; if fires are too frequent, they can't reproduce.

All of this also affects animal habitat. "We have a pretty resilient landscape," says Barnes, but some wildlife depends on older forests, and ecosystems that have long since recovered from fire. Birds like the boreal owl only nest in older trees, for example, and caribou eat lichen that can take 50 years to recover after fire.

Food scarcity can ripple out to the people who rely on these animals, too. Before this summer's fires around St Mary's, the Yukon river salmon runs were already at record lows, probably due at least in part to ocean warming.

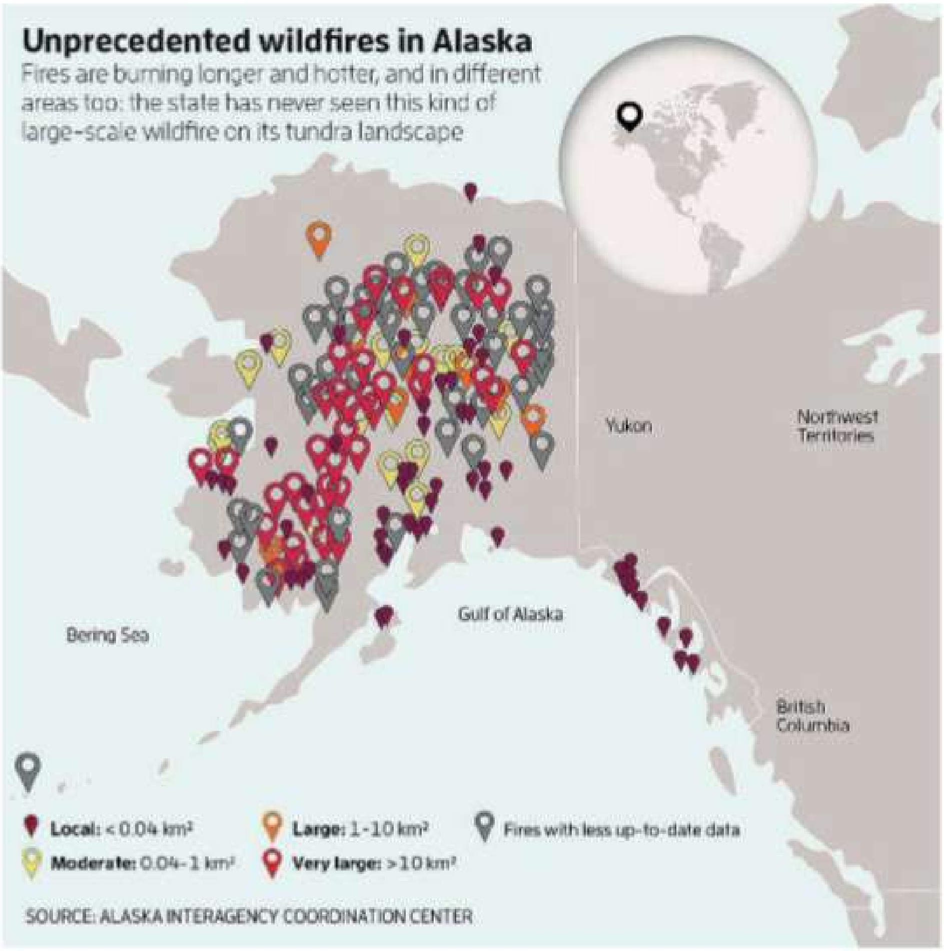
AP/SHUTTERSTOCK

An aerial view of the Kichatna wildfire in southern Alaska in June

Research questions about Arctic wildfires tend to centre on things like carbon emissions. But in communities like St Mary's, food from the land is an important part of culture, and expensive to replace in a grocery store. After a fire, erosion increases river sediment and debris, which can suffocate salmon eggs left without clean gravel beds and oxygenated water. With surrounding vegetation burned away, there is also less shade over the water, so rivers can get warmer, says Erik Schoen at the University of Alaska Fairbanks. Even before the fire, river temperatures near St Mary's could get warm enough to cause heat stress for adult salmon. "Is this just the nail in the coffin for fish returning?" asks Smith.

Another big question now will be how scientists, government and the people of Alaska come together in the face of such challenges. "Communities in regions where wildfire has not historically been a significant risk are going to have to think much more about fire than they ever have in the past," says Thoman.

That doesn't just mean learning how to cut firebreaks by hacking back shrubs to starve fires of fuel. Burning thousands of square kilometres generates lots of smoke. For weeks this summer, the air quality index for the interior of the state was often "hazardous" – meaning particulate pollution was often above 300 parts per million, levels that can trigger asthma and cause long-lasting health impacts. In the 1950s, the city of Fairbanks had a roughly 70 per cent chance that any given summer would have zero hours with visibility reducing smoke. "Now, that's down to about 10 per cent," says Thoman.


Unprecedented wildfires in Alaska

Fires are burning longer and hotter, and in different areas too: the state has never seen this kind of large-scale wildfire on its tundra landscape

SOURCE: ALASKA INTERAGENCY COORDINATION CENTER

As fire seasons worsen, both communities and resources will come under pressure. Alaska often relies on fire crews and equipment from the mainland US states. But when everyone is facing more fires, fewer crews are available.

Fire isn't the only growing challenge. In recent weeks, several places in Alaska have broken single-day rainfall records that had stood for a century. "There is no one-size-fits-all situation in the Arctic," says Rodríguez-Cardona.

> **"If these trends continue, there's a threshold after which the ecosystem may never recover"**

Yet that variation is what makes Alaska so important, says Fresco. The Arctic is a vast place, and its ecosystems are uniquely intact, spared from the fragmentation that human development caused in other places around the world. Animals can find undisturbed habitat even after natural disasters. Its undeveloped nature has also helped it to maintain such significant carbon stores. Alaska is a proving ground for both climate mitigation and adaptation, says Fresco. "It's a crucial and obviously irreplaceable place." ▮

Field notes A weevil lab near London, UK

How weevils have become weapons in the UK's fight against invasive plants

Adam Vaughan

HOUSED in a food container and measuring just 0.5 centimetres long, the weevil doesn't look very menacing. Yet this specimen of *Listronotus elongatus* is the UK's latest hope in a new wave of biological ways to control invasive species rather than using chemical and mechanical methods.

The South American creature's target is floating pennywort (*Hydrocotyle ranunculoides*), an invasive plant that chokes rivers, cutting water oxygen levels and outcompeting native plants.

The weevil I saw – in a lab near London belonging to the Centre for Agriculture and Bioscience International (CABI) – will eat the plant's leaves and its larvae will eat the stalks from the inside out.

The weevils (one is pictured) were first deployed in the wild in the UK last winter. More will be released in various areas this year to tackle the pennywort problem. "It just keeps coming back," says Djami Djeddour at CABI.

As well as threatening biodiversity, problem invasive species have an economic burden estimated at £1.7 billion a year in Great Britain. Those are two reasons why the weevil is at the forefront of a new wave of biological agents used in the UK since tiny, plant-feeding insects called psyllids were released to tackle Japanese knotweed (*Reynoutria japonica*) in 2010.

CABI

This weevil eats floating pennywort, an invasive aquatic plant

It is fair to say that the sap-sucking psyllids have failed to make much headway against knotweed. However, a different weevil, *Stenopelmus rufinasus*, does seem to making inroads in the UK against a problem aquatic fern called *Azolla filiculoides*.

This mixed record leaves the CABI team still searching for a big success. The centre's director, Dick Shaw, is pinning his hopes on the efforts against pennywort: "It has a very high likelihood of success, because it's a floating plant and a weevil, and the history of that is just fantastic around the world."

Biological controls have worked well in certain places: of 468 agents released in 90 countries, 71 per cent established themselves and 55 per cent caused medium or heavy damage to the target species.

But some have had unintended consequences, such as harlequin ladybirds released to kill aphids wiping out other ladybird species, and weevils introduced in Canada to tackle an invasive thistle attacking native ones too.

Yet less then a tenth of biological agents attack non-target species. This is because of hard work designed to reduce the risk.

To try to ensure that *L. elongatus* doesn't devour anything else, Djeddour and her colleagues undertook tests in Argentina on the 10 or so plant species that live next to floating pennywort, and 70 possible target plants were tried in the UK. Those tests include the "no-choice" test. "It's basically a starvation test where you get them on a plant and if they don't feed on it, they die," says Djeddour. Four other agents for floating pennywort were dismissed.

£1.7bn

Annual economic burden of invasive species in Great Britain

Nothing is unleashed unless a UK government licence is granted, which allows releases for three years. The next hurdles will be whether the weevils can establish themselves in the wild and be effective against the pennywort.

Shaw is optimistic about the weevils, but he is trying to temper hopes. "We've learned over time that raising expectations, if you keep failing, isn't a good model," he says. ▮

Games

Quantum computers better at Wordle than classical ones

IF YOU struggle with Wordle, you might just need to think like a quantum computer. Quantum algorithms will always do better in the long run at this game and similar ones than their classical counterparts.

Lvzhou Li at Sun Yat-sen University in China and his colleagues developed a quantum algorithm for the game Mastermind, which has many of the same underlying principles as Wordle.

In the game, a "codemaker" chooses four pegs, each of which can be one of six colours, and arranges them in a pattern. The "codebreaker" then uses a series of guesses to determine the arrangement of the pegs. In Wordle, the set-up is very similar, except that the codebreaker has to guess a five-letter word.

Li and the team based their quantum Mastermind strategy on a well-known quantum codebreaking algorithm that has previously been used in real-world cryptography. It relies on the idea of quantum superposition where the many possibilities of how something can exist are expressed by one mathematical function. As a result, the codebreaker can very efficiently make many guesses at once (*arXiv*, doi.org/h67f).

"Our work shows the Wordle game can also be more easily won on quantum computers," says Li.

David Meyer at the University of California San Diego says that though physicists and computer scientists have known that quantum algorithms may excel in situations where information is uncovered through a sequence of guesses, the new result shows how this works in a specific situation. "It's nice to see a quantum algorithm where there are real problems that they can really be better for," he says.

"Our work shows the Wordle game can be more easily won on quantum computers"

However, existing quantum computers are too small and error-prone to be able to implement the algorithm yet, says André Suoto at the University of Lisbon in Portugal. ▮

Karmela Padavic-Callaghan

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Technology

Thumbs up for video call hand signals

USING simple gestures during video calls seems to improve the experience.

During lockdowns, Paul Hills at University College London came up with a set of hand gestures that he called Video Meeting Signals. These include a hand over your heart to signify empathy and thumbs up or down for agreement or disagreement.

With colleagues, he set up a randomised trial to test them involving about 120 students.

Half of them were asked to use the signals in seminars done by video call, and a control group had video meetings, but didn't use the signs. Participants reported in surveys afterwards that their group affiliation felt stronger because of their use of the gestures (*PLoS One*, doi.org/gqk4vd). **Chris Stokel-Walker**

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Health

First steps towards a bronchiolitis vaccine

AN EXPERIMENTAL vaccine has shown promise at protecting mice from the respiratory syncytial virus (RSV), which most commonly causes the chest infection bronchiolitis in young children.

Ofer Levy at Boston Children's Hospital and his team used immune-stimulating molecules, called adjuvants, along with a fragment of a protein that RSV uses to enter cells, to develop a vaccine.

To test it, newborn mice were injected with vaccine or saline and then exposed to RSV seven weeks later. About two weeks after this, the virus was found in the lungs of the mice that were given saline, but not in the vaccinated mice. The concentration of RSV in the noses of the vaccinated mice was also 100 times lower (*Nature Communications*, doi.org/h7bk). Tests in other animals and then people are planned. **Carissa Wong**

Botany

Meat-eating plant has a trick to ensure it gets a meal

THE slender pitcher plant of South-East Asia has a leafy lid that acts like a springboard, launching prey into a deep cavity filled with digestive juices. Now, we have figured out how this macabre machinery works.

Carnivorous pitcher plants have specialised leaves shaped like elongated sacks that hold digestive fluid. The vessels are baited with nectar to lure unsuspecting insects and lined on the inside with slippery wax that sends the critters tumbling towards death.

Typically, insects just slip in, unable to cling to the waxy inner lining. But the slender pitcher plant (*Nepenthes gracilis*, pictured) plays a more active role. It baits ants to the underside of the leafy lid covering the pitcher. Then, when raindrops hit the lid, this triggers fast twitches in the plant that catapult prey into the gastric pool below.

To find the elastic components behind the trap, Anne-Kristin Lenz at the University of Bristol in the UK and her colleagues used high-powered X-rays in order to see inside the plants as they recoiled during rainfall.

When rain strikes the lid, it flexes down, channelling energy through the narrow neck connecting it to the pitcher and compressing a springy region several centimetres down the body of the pitcher. Then, the plant releases stored elastic energy and the lid springs up. This motion whiplashes insects into the trap (*Biology Letters*, doi.org/h69w).

"It's remarkable that such a thing has evolved," says Simon Poppinga at the Technical University of Darmstadt in Germany. The discovery of the plant's mechanics could lend itself to technology, he says. **Jason P. Dinh**

Really brief

ARCO/J. FIEBER/IMAGEBROKER/ALAMY

Mice engineered to produce rat sperm

Mice have produced rat sperm after rat stem cells were implanted into a modified mouse embryo. The method could one day allow us to create human-rat hybrids for biomedical research or help save endangered species (*Stem Cell Reports*, doi.org/gqk8zv).

Smart finger can sense materials

An artificial finger that can identify different materials by their surface could be used to automate robotic manufacturing tasks. When tested on hundreds of samples such as wood, glass and plastic, the finger achieved an accuracy of nearly 97 per cent (*Science Advances*, doi.org/h7h6).

Climate change worsens diseases

The impacts of climate change are making most infectious diseases worse, according to a review of published studies. It found that 10 "climate hazards", including flooding and heatwaves, had increased the severity of 58 per cent of 375 transmissible diseases looked at in the analysis (*Nature Climate Change*, DOI: 10.1038/s41559-022-01426-1).

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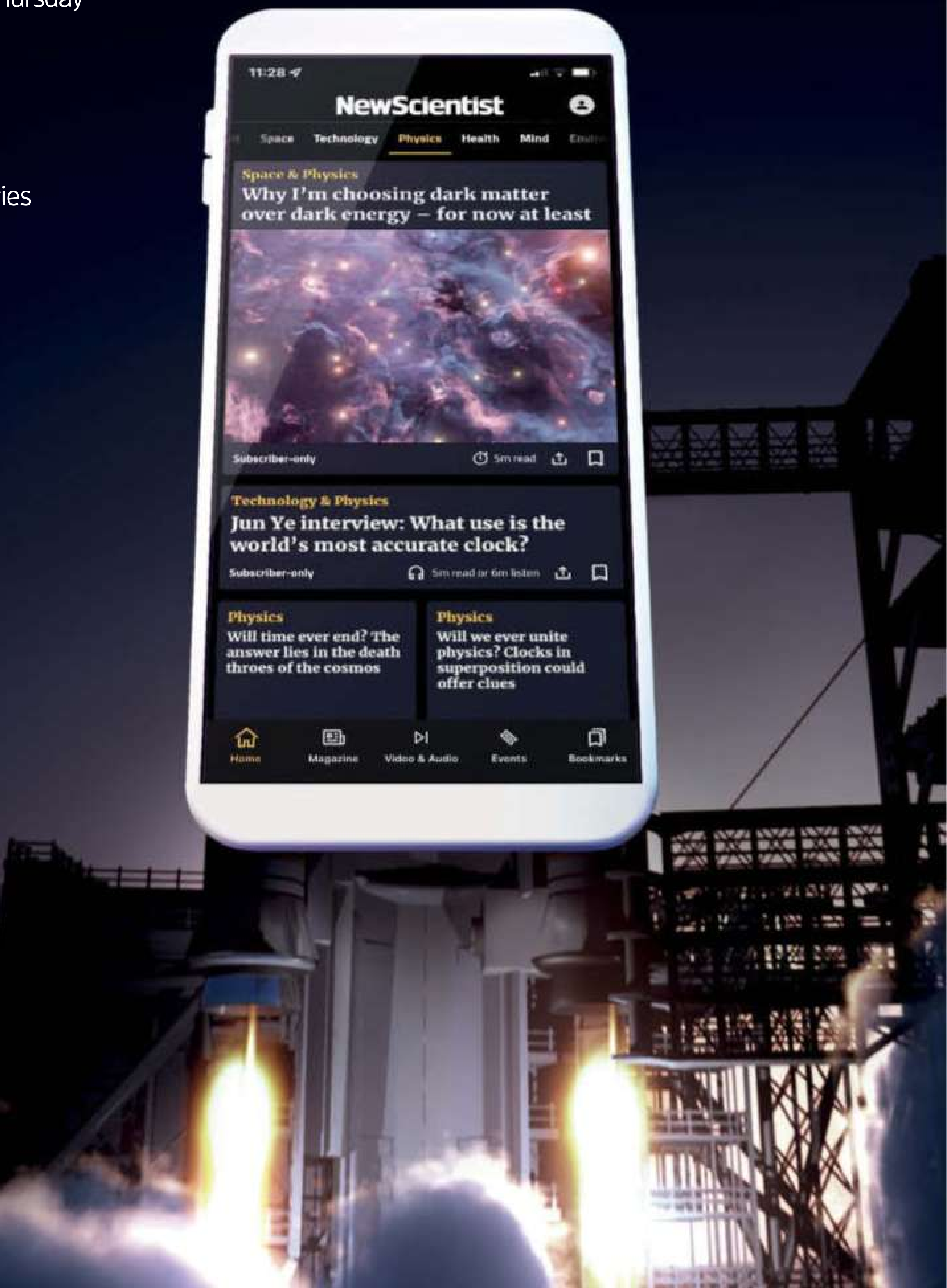

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Views

The columnist **Graham Lawton** on Chile's green constitution p28

Aperture A close-up view of the unwanted guests of ants p30

Letters Diving deeper into blue spaces and their impact on mood p33

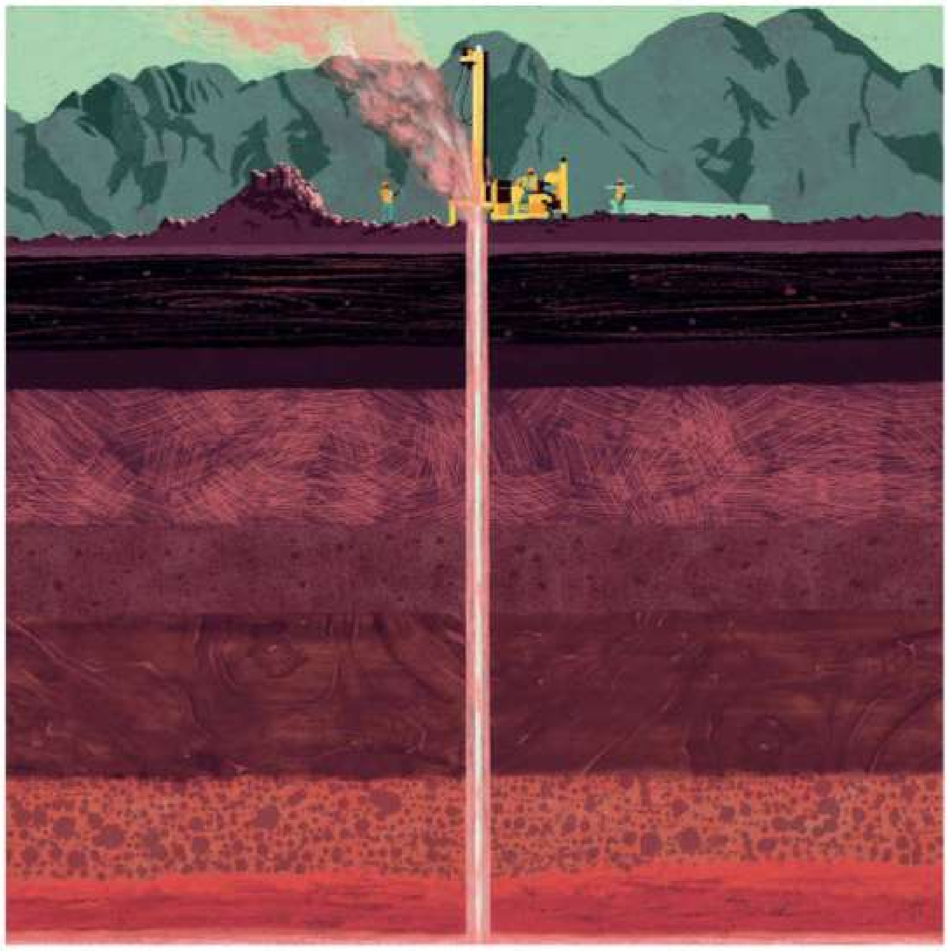
Culture An exhibition looks at the effects of naval sonar on whales p34

Culture columnist **Bethan Ackerley** watches a harrowing hospital drama p36

Comment

Drilling deep

Millimetre-wave beam technology could tap deep geothermal energy. The world must work together to make it happen, says **Eugene Linden**



SIMONE ROTELLA

FOR years, those looking to generate electricity without using fossil fuels have dreamed of tapping the virtually unlimited heat source that lies 8 kilometres or more beneath Earth's surface. Prior efforts have been stymied because getting to that heat entails drilling into rock that is too hard for conventional techniques. Now, one tantalising possibility involves repurposing an existing technology to tap into this source and produce electricity at a lower cost than any existing form of power generation.

This isn't, however, simply a matter of economics. Even if all nations were to meet the pledges that were made under the Paris Agreement on climate change, temperatures are expected to rise by roughly 3°C by 2100. Tapping into deep geothermal energy has the promise of replacing fossil fuel-powered plants at the scale required to avert this catastrophe.

The technology that might enable this, which makes use of millimetre-wave beams, was optimised for fusion research at the Massachusetts Institute of Technology and could provide access to the 400°C to 500°C heat that lies several kilometres below Earth's surface. Extracted through a borehole, this heat could produce steam for electricity generation as a zero-carbon substitute for fossil fuels.

The opportunity is huge. Coal-fuelled, steam-powered turbines are the largest single source of human-caused greenhouse gas emissions. The great majority of these turbines could be retrofitted to use steam from deep geothermal energy, and would produce electricity at less cost than any fossil fuel as a consequence.

Until now, the problem has been that once past the sedimentary rock constituting the first few kilometres of Earth's crust, drillers hit granite or basalt that is five to 10 times harder and resistant to standard techniques.

Enter millimetre-wave beams. These are similar to, but vastly more powerful than, the waves used in a microwave oven. Created by a device called a gyrotron, these waves have now been proven to vaporise rock, according to Carlos Araque, CEO of start-up Quaise Energy, which has a licence to commercialise the technology for deep drilling. Combined with conventional drilling, it might be possible to create a borehole reaching reservoirs of deep heat. Araque says he expects Quaise Energy will be able to drill such deep holes in as little as 100 days. Another start-up, GA Drilling, is attempting a similar thing using ultra-high temperature plasmas.

Time is money, so drilling this rapidly greatly reduces costs. Araque estimates that a freshly built, deep geothermal plant will produce electricity at 1 to 3 cents per kilowatt-hour (including capital costs), which is as cheap as, or cheaper than, any electric power generator now operating. Retrofitting an existing coal or gas plant to use steam from deep geothermal energy could produce electricity for less than 1 cent per kilowatt-hour, he says.

That is the genius of this technology: it meshes with existing infrastructure and expertise. As it is just an extension of conventional drilling, it doesn't produce the seismic problems associated with fracking. The biggest hurdle will be delivering and focusing the millimetre-wave beams so deep underground.

This challenge can and must be met. Quaise Energy plans to complete a shallow pilot project next year and then construct two deep drill holes in 2024. If its approach proves feasible, deep geothermal energy could be deployed extremely rapidly.

The speed with which a covid-19 vaccine was produced showed what the world can do when faced with an emergency. Deep geothermal energy promises to be the equivalent of a vaccine for the climate emergency. ▮

Eugene Linden's latest book is *Fire and Flood: A people's history of climate change from 1979 to the present*

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No planet B

Natural law Chile's draft constitution has an almost unparalleled commitment to the environment. If adopted, it would make Chile the first truly ecological state, says **Graham Lawton**

Graham Lawton is a staff writer at *New Scientist* and author of *Mustn't Grumble: The surprising science of everyday ailments*. You can follow him @grahamlawton

Graham's week

What I'm reading

I'm more into podcasts at the moment. Stories of Our Times: Last man standing *is an amazing account of the kidnapping of journalist John Cantlie in Syria in 2012.*

What I'm watching

Season two of The Great.

What I'm working on

Saving my tree fern from drought.

This column appears monthly. Up next week: Annalee Newitz

LATER this year, a pivotal vote is due to take place in South America. If it goes the right way, a country seemingly addicted to environmental destruction in the name of profit will finally decide that enough is enough.

I am not talking about the Brazilian presidential election on 2 October, though the defeat of Jair Bolsonaro would be worth celebrating. A month earlier, Chileans will go to the polls to decide whether to scrap their constitution and adopt a new one. If the answer is yes, Chile will set about turning itself into a new type of civilisation.

Chile's current constitution dates from 1980, during the military dictatorship led by Augusto Pinochet. Inspired by neoliberal economics, it enshrined free markets, deregulation and private property rights into the heart of Chilean law.

This system – largely kept intact after the restoration of democracy in 1990 – has arguably served the nation well, at least from the perspective of economic growth. Chile is one of South America's wealthiest countries, but it is also one of the most unequal and environmentally despoiled.

Those cracks are now straining Chilean society to the limit. September's plebiscite was ostensibly triggered by a wave of massive street protests that started in Santiago in October 2019. The immediate cause was subway fare rises, but the demonstrations quickly gave voice to other festering grievances, chiefly environmental injustices and water shortages, according to Ezio Costa at the University of Chile. Both can be attributed to the 1980 constitution, which created so-called industrial sacrifice zones with little or no protection for workers or the environment, and cemented private property rights over water rights.

One of the protesters' demands was for a new constitution. In November 2019, the Chilean government agreed to hold a referendum on creating one. The vote happened in October 2020 and the proposal won by a landslide, albeit on a turnout of just over 50 per cent. In May, Chileans elected the Constitutional Assembly to draft the document. Most of its 155 seats were won by left-leaning private citizens with no experience of politics or constitutional law.

The final draft of the proposed constitution was published on 4 July and will be put to yet another vote on 4 September. It is, says David Boyd, the United Nations special rapporteur on human rights and the environment, a "remarkable document" and a "dramatic departure from the current Chilean constitution".

> "Despite strong initial public support for the new constitution, polls now show growing opposition"

In large part, that is because of its almost unprecedented commitment to the environment. The document styles itself as an "ecological constitution": of 311 articles, 80 are concerned in some way with protection of the natural world. An entire chapter (24 articles) is devoted to nature and the environment, explicitly recognising the climate and ecological crises and committing the state to solving them. All told, says Costa, the constitution would compel the state to "exist without destroying nature". Or, to coin a slogan: "Make Chile ecological again!"

According to Boyd, the draft constitution is one of the two most environmentally progressive in the world, the other being Ecuador's, which came into force in 2008 and was the first to recognise the rights of nature. But Ecuador has struggled to implement its constitution and, if fully enacted, Chile's would make it the first truly ecological state.

If this sounds too idealistic to be true, that is because it probably is. Despite strong initial public support for the new constitution, opinion polls in Chile now show solid and growing opposition to ratifying it. The most likely outcome on 4 September is a decisive vote for the status quo.

What went wrong? According to journalist Marcel Oppliger at Chile's *Diario Financiero*, the Constitutional Assembly took it upon itself to radically refound the country and overreached, proposing, for example, the abolition of the Senate, while ignoring many of the grievances that brought it about. As a result, popular support collapsed.

If Chile rejects the document, then green ambitions aren't lost. Chile's 1980 constitution isn't set in stone. Since 1990, it has been amended 22 times and could be retooled again. Other countries in the region, such as Costa Rica, have gone green through concise constitutional amendments.

And even in electoral defeat, Chile's constitutional movement will have won the argument to create a greener, fairer nation. "One of my favourite quotes is from a South African judge who said that a constitution is like a mirror of a country's soul," says Boyd. "If this proposed constitution is a mirror of the Chilean soul, then, my, what a beautiful soul that is."

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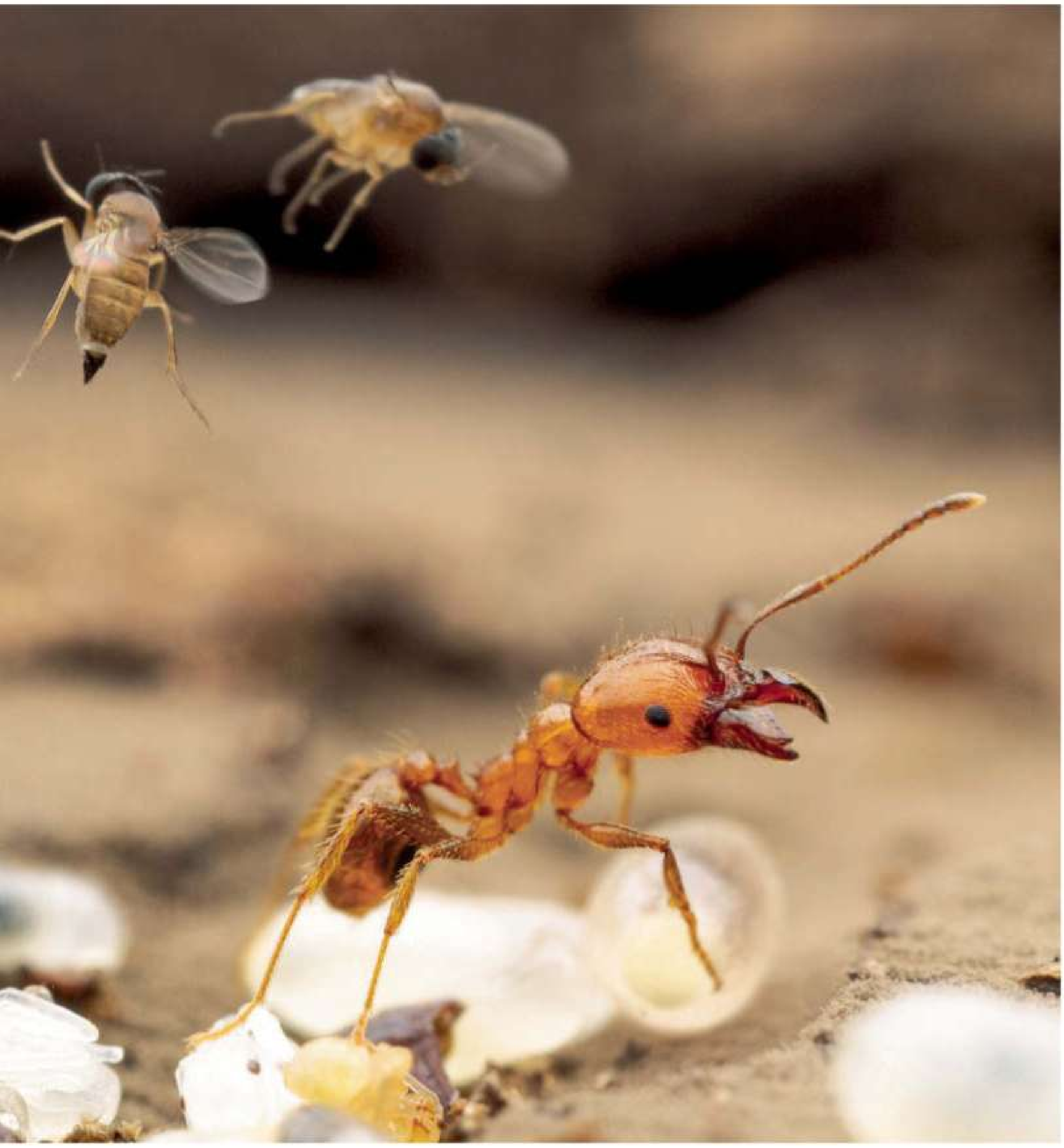

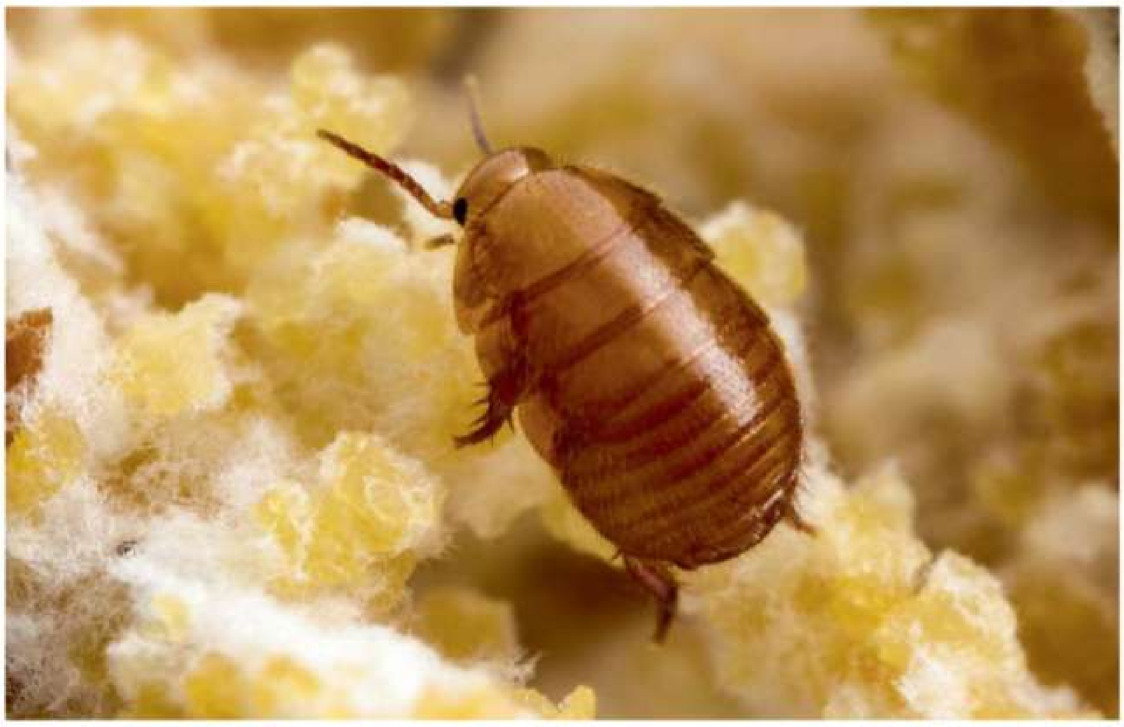

Space invaders

ANTS are known for their remarkably sophisticated colonies, coordinating their behaviours to transform a pile of dirt into a complex structure in as little as a week – but there are other sophisticated organisms out there looking to infiltrate these carefully set up societies.

The invaders, collectively called myrmecophiles, are the topic of *The Guests of Ants*, a new book by biologist Bert Hölldobler and behavioural ecologist Christina Kwapich. The pair examine the species that disrupt colonies by taking advantage of them, whether by masquerading as ants or manipulating their behaviour.

These images are taken from the book. At top left, a histerid beetle (*Haeterius ferrugineus*) is shown among a brood of *Formica* ant larvae, which it has been reported to prey on. The beetle has also been seen to solicit regurgitated food from the host ants, attracting their attention by waving its forelegs.

Other ant attackers include *Apocephalus*, a type of ant-decapitating fly, shown attacking a soldier *Pheidole dentata* ant (top right), and the larva of the moth *Ippa conspersa*, seen assaulting a worker of a host ant (probably of the species *Lasius nipponensis*), at bottom centre.

Attaphila fungicola, a cockroach that lives in the nests of the Texas leafcutter ant (*Atta texana*) and rides on winged queens when they leave the nest for mating, feeds on a colony's cultured fungus in the image at bottom right. At bottom left, a *Microdon* hoverfly larva sits in the nest of the *Linepithema oblongum* ant. The fly larvae are usually ignored and tolerated by the ants, even as they prey on the ants' brood of larvae.

Gege Li

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Editor's pick

Some want upheavals of a darker nature

23 July, p 42

From Paul Whiteley, Bittaford, Devon, UK

It is interesting to note that, when it comes to the upheaval that plagues and other calamities can have on societies, certain people view things very differently. They certainly don't see disasters as catalysing a shift to something better for the wider world.

There are some religious groups that would welcome catastrophes of various sorts: at one time it was nuclear war, lately it has been climate change. They believe such calamities would be signs of the Rapture or the end times. For them, even sea level rise can encourage notions of Noah and the cleansing of Earth. They think they will survive while the rest of us perish. So much for building back better.

Diving deeper into nature's impact on us

16 July, p 38

From John Cantellow, Derby, UK

"Into the blue" comprehensively conveyed the psychological benefits of both green and blue spaces. However, I was intrigued by the reference to the calming effects of blue spaces.

We have known for some time that blue has a stimulating, not a calming, effect due to melanopsin receptors in the eye that are particularly sensitive to blue light. This causes excitation of the suprachiasmatic nucleus of the brain, the master biological clock, and releases wake-up hormones, such as cortisol.

For me, this begs the question: what is the physiology that underpins the calming effect of proximity to water?

From Robert Fizek, Newton, Massachusetts, US

Given the limited proximity of urban populations to natural bodies of water, I would like to delve into the effects of moving water features in urban settings.

Having lived for a while in central Rome, I can attest to the great relief you can find in the sight and sound of flowing water in fountains and so on, and in the fascinating diversity of observations that can be made of splashing water in the piazzas, which you might encounter on casual walks to work or shopping.

Even the echoes of a little street fountain, or of the one found in the small courtyard below our bedroom windows, were soothing in the night.

Non-metric systems do have some upsides

Letters, 16 July

From Rosemary Sharples, Sydney, Australia

There are good reasons why the metric system isn't favoured by some people. Apart from having to learn another system when the one in use is perfectly adequate for their needs, the metric system isn't as good for some transactions as, for example, a system based on multiples of 12, which are more flexible. Multiples of 12 allow you to easily divide quantities of food, fabric, liquids and so on into thirds or quarters, as well as halves. These divisions are easier to determine by eye than when doing the same with multiples of 10.

Can space telescope put big bang to the test?

30 July, p 9

From William Hughes-Games, Waipara, New Zealand

Now that the James Webb Space Telescope can see really distant objects, with redshifts that equate to the early universe, surely there is a simple test for the big bang theory. The further away we look, and hence the further back in time, the lower the concentration should be of elements heavier than hydrogen and helium. If not, then it's back to the drawing board.

Did short dino arms avoid self-inflicted injuries?

16 July, p 23

From Stephen Robinson, London, UK

It was fascinating to read of *Meraxes gigas*, a newly described dinosaur with a large head and sharp teeth, which walked on powerful hind legs and yet had proportionately small arms. Though other reasons for "small" arms in the likes of *T. rex* have been put forward, I suspect it is mainly to do with their huge jaws.

Flinging around a fridge-sized head filled with rows of huge, sharp teeth isn't only dangerous for the unfortunate prey, but also for the predator. The longer the creature's arms, the more chance of them being bitten off in the melee by another pack member, or even their owner.

Seeing time through the eyes of various cultures

18 June, p 38

From Bonita Ely, Sydney, Australia

"Mysteries of the fourth dimension" didn't address how different cultures perceive time. For example, the Hindu tradition views time as cycles of ages that arise out of darkness or dissolution. Aeons follow each other in rotating cycles, repeating similar events and developments and each time concluding with a universal dissolution into divine, primal substance.

For Indigenous Australians in the central desert area, the past doesn't exist in a distant time. Instead, it is concurrent with the present, embodied in current generations who preserve it and pass it on. Past and present coexist, as they do in Albert Einstein's "block universe".

Could these cultures have insights into time that scientists are now grappling with?

New coal mine may have some merits

16 July, p 28

From Richard Mellish, London, UK

Adam Vaughan argues against the opening of a new coal mine in Cumbria, UK. However, the promoters of the mine must be confident of the market for the coking coal that it would produce. If that mine doesn't open, will that market miraculously vanish or will the same amount of coal come from mines elsewhere in the world, perhaps where safety receives less attention?

Of course the steel industry should be (and is) moving towards better methods that will emit less carbon dioxide, and perhaps that will happen faster than the promoters of the mine expect, but the rate of decline of the demand for coal will depend very little on where the coal comes from.

Four legs or six, it's all just meat

Letters, 9 July

From Simon Goodman, Griesheim, Germany

I am fascinated by those like Roger Browne who feel that the "yuck" factor will be an obstacle in the transition toward more insect-based diets.

Meat eaters may wish to consider how a gambolling little lamb becomes the pile of bloody lamb chops they might have with mint sauce for their lunch. As they, the main target for insect foods, already deal with this, the step from eating animals with four legs to six should be relatively easy. ▮

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What a dead whale can tell us

A beaked whale carcass washed up on a Scottish beach in 2018, part of a mass stranding across multiple coasts. It is now at the heart of an artistic challenge to the military, finds **David Stock**

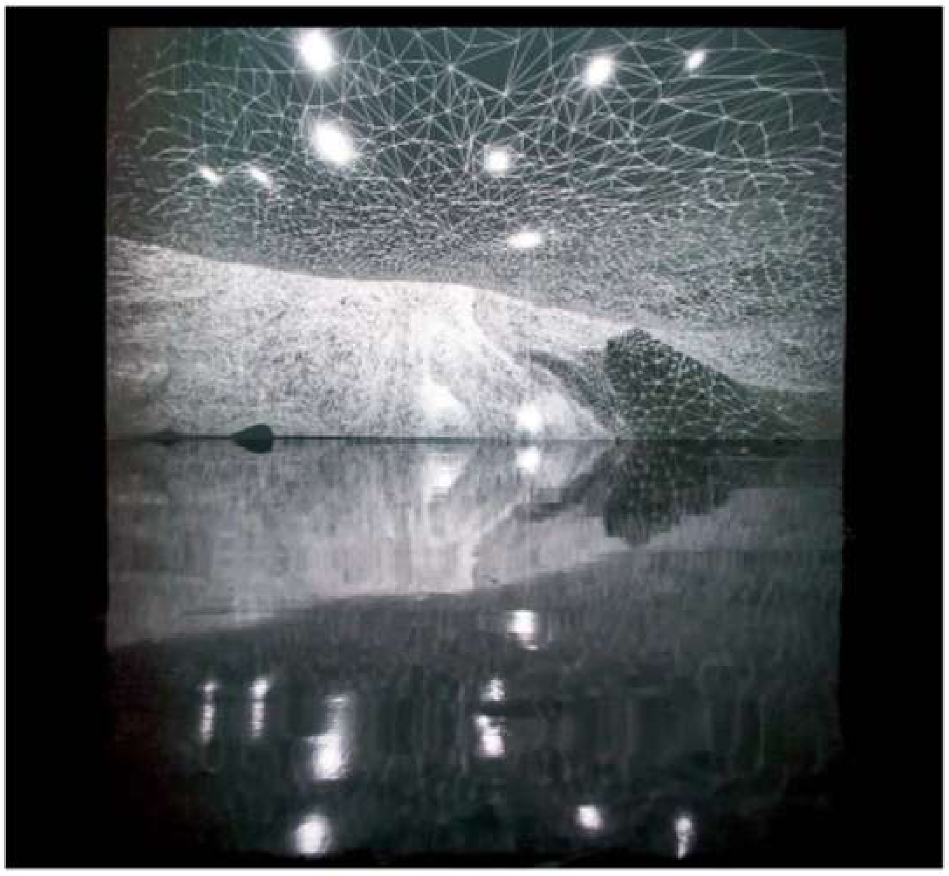
Exhibition

On Sonorous Seas

An exhibition led by Mhairi Killin in collaboration with others

An Tobar, Isle of Mull, UK

Closes 27 August



SARAH DARLING

A "constellation" of data points showing where the dead whales washed up

DAVID STOCK

Calligraphy by Susie Leiper on the remains of a Cuvier's beaked whale

SOMETIMES art and science come together to raise our awareness of a compelling issue. One such occasion is a multimedia exhibition called *On Sonorous Seas*, led by artist Mhairi Killin and prompted by her experience of a mass stranding of dead whales.

At the An Tobar gallery on the Isle of Mull in the Inner Hebrides, UK, Killin explores the complex relationship between biodiversity and militarisation in Scottish waters, using science, sculpture and sound to show how our oceans are increasingly full of human-made noise that is killing whales.

In 2018, the carcasses of more than 100 beaked whales washed up in a mass stranding around the coasts of Scotland, Ireland, Iceland and the Faroe Islands. One carcass washed up on Iona, the Hebridean island where Killin lives. The event was one of the largest of its kind, with evidence pointing to human causes – particularly to military activity in the region.

Killin had been considering an art project exploring the presence of the military in the Hebrides, so she approached the Hebridean Whale and Dolphin Trust (HWDT), which was worried about the impact of mid-range sonar on cetaceans. The trust was already investigating this by collecting acoustic and visual data during the biannual NATO Joint Warrior exercises off the Scottish shores.

"I knew that if the trust was concerned, then there was an area of concern and I wanted to be part of that," says Killin. The HWDT welcomed her onto its research vessel, the Silurian, as a citizen scientist on a 10-day expedition coinciding with the 2021 naval manoeuvres. Her experiences turned into *On Sonorous Seas*.

Killin used scientific data she collected as a "conduit to another world", the secretive world of whales and the military. This is reflected in a piece she created with Fergus Hall, a Glasgow-based composer. It is a soundtrack of mostly underwater recordings to accompany *A Constellation of Strandings*, a 45-minute multimedia work made with digital artist Tom deMajo.

Replicating the world of deep-diving whales, the experience occupies the larger of An Tobar's exhibition rooms, creating a dark, void-like space full of clicks, whirrs and rumbles from the recordings. So much cetacean experience is through sound, says Hall, which is why human-made noise can be so damaging. "If you're an animal that experiences your world through sound, then it's almost like you've been blinded," he says.

Using a hydrophone to record underwater, HWDT researchers study the changes in noise over time. The recordings often include porpoise clicks, dolphin whistles and whale songs. However, sounds from boats, acoustic deterrent devices (used to scare off cetaceans in fish farms) or from dredging and trawling are increasingly common. We have industrialised the oceans, making them more dangerous and noisy for marine animals, says Andrew Brownlow, a pathologist for the Scottish Marine Animal Stranding Scheme, who studied the 2018 strandings.

This human-made noise in oceans can change behaviours, disorienting whales and leaving them unable to communicate or forcing them into more hazardous areas. In extreme cases, it causes whales to surface too quickly, creating decompression sickness.

Beaked whales are a deep-diving species that communicate and hunt through mid-range sonar frequencies. Unfortunately, so does the military. By combining pathology results from the dead beaked whales with the audio data collected by the HWDT, Brownlow and his team identified the most likely location of the whales in 2018: in the region of the Rockall Trough and the Porcupine Seabight, north-west of Scotland.

In 2021, the British Navy admitted it was present in that area in 2018. "It seems there's this overlap between areas that are important for tactical military use and areas that are important for beaked whales," says Brownlow.

> **"Human-made noise can change behaviours, disorienting whales and forcing them into more hazardous areas"**

In 2004, following a spate of cetacean strandings in the Canary Islands linked to naval exercises, the Spanish government imposed a moratorium on certain sonar frequencies. Since then, no mass

New Scientist video
Watch video of Mhairi Killin discussing her work at **youtube.com/newscientist**

strandings have been recorded.

Back at the gallery, on-screen pulses in *A Constellation of Strandings* remind us of sonar screens. Connected by thin lines, a stellar constellation starts to appear. It is only when a map of the Hebridean islands comes into focus that the significance of these dots is clear: they are data points, representing sites where whales were stranded in 2018 (see top left). This motif repeats on the opposite wall, now as silver casts of whale ear bones, from 3D scans created by the National Museum of Scotland.

A quieter room showcases a poem by Miek Zwamborn, with calligraphic artwork by Susie Leiper using spectrograms (visual representations of the sound recordings). Hanging from the ceiling is the skull of a Cuvier's beaked whale, washed up on the Isle of Harris in 2018 – a visceral reminder of what little remains of the magnificent mammals.

While the 2018 stranding was large and not a one-off, most people still know little about the effects of anthropogenic sound, says Killin. Talking to her and the researchers, and sailing on the Silurian – albeit not in the shadow of a military operation – gives you a better understanding. But it also leaves you dismayed by how little time we take to contemplate the vast world in our seas and the beautiful animals dying in droves from avoidable human activity.

There is a balance to be struck between justifiable activity in our oceans, military or otherwise, and the effect it has on these important species. *On Sonorous Seas* explores the hidden world of cetaceans in an engaging way, turning scientific research into an accessible and powerful narrative. It shows us what we need to learn to start sharing Earth with other animals.

If you can get to Mull, do. ▮

No norms here

There is no such thing as normal for humans, argues a new book. **Simon Ings** investigates

Book

Am I Normal?

Sarah Chaney

Wellcome Collection

A PAIR of unusual gloves, belonging to 19th-century polymath Francis Galton, lie in University College London. Galton was the man who coined the term eugenics to describe beliefs and practices that aim to "improve" the genetic quality of a human population.

His motto was "whenever you can, count", so he decided to put a pin in the thumb of his left glove and a felt pad, covered by a strip of paper, across its fingers. By touching different fingers with the pin, Galton could track the things he saw without others noticing.

One of Galton's ideas was to assemble a beauty map of Great Britain. Women he judged to be beautiful were noted with pinpricks on one finger, while those he deemed plain were marked on another. Clearly, this wouldn't produce a map of British physiognomic variation so much as a record of Galton's prejudices and tastes.

In *Am I Normal? The 200-year search for normal people (and why they don't exist)*, Sarah Chaney uses such examples to make clear that, when it comes to society, the human body and the mind, there can be no such thing as an objective study; there is no moral or existential "outside" from which to begin one.

HENRIK SORENSEN/GETTY IMAGES

The idea that there could be a "normal" person has obsessed thinkers for centuries

Chaney's book provides an uncomfortable context for our attempts to seek norms. Most studies reflect the prejudices of their time. Take drapetomania, a "mental illness" proposed in 1851 to affect enslaved people who ran away: slave life was thought to be so pleasant that only those with mental health problems would want to escape.

It would be easy to wield such horrors against the medical and social sciences, especially since measurement has elicited little insight in some areas – note the relatively slow progress in our understanding of mental health. But given the severe symptoms of some medical conditions, do we really want to abandon our efforts to understand them?

It is true that we haven't paid enough attention to the source and use of our data. Should we still base medicine, social policy and design largely on data from people in Western, educated, industrialised, rich and democratic (WEIRD) societies?

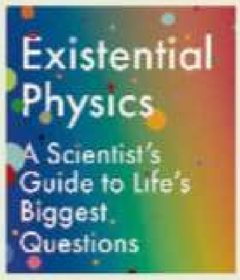
Luckily, says Chaney, studies can easily be made to detect diversity instead. It just takes humility, imagination and an awareness that there may be no such thing as normal. ▮

Simon Ings is a writer based in London

Don't miss

Watch

Look Both Ways stars Lili Reinhart as Natalie, whose life splits into parallel realities on the eve of her graduation. She either heads to Los Angeles to pursue a career, or stays at home with her baby. On Netflix from 17 August.



Read

Existential Physics speaks to the big stuff: is the universe compatible with God? Does free will exist? Theoretical physicist Sabine Hossenfelder shows how the latest research gives insight into age-old problems. On sale from 18 August.

Visit

The Neuroscience of Creativity is revealed by neuroscientist Jonathan Iliff, who explores how brains transform life into art, invention and even wondering if we need a glass of milk. At Juju's Bar and Stage, London, 7pm BST on 16 August.

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The TV column

In real life *Five Days at Memorial*, based on the book by Sheri Fink, tells the shocking stories of health workers and patients whose lives are changed forever as Hurricane Katrina overwhelms a hospital in 2005. **Bethan Ackerley** explores

Bethan Ackerley is a subeditor at *New Scientist*. Follow her on Twitter @inkerley

COURTESY OF APPLE

Anna Pou (Vera Farmiga), front, and Karen Wynn (Adepero Oduye)

TV

Five Days at Memorial

Apple TV+

ON 11 September 2005, 45 bodies were recovered from Memorial Medical Center, New Orleans. The hospital had been hit by Hurricane Katrina, then the most devastating storm in US history. Patients, staff and their families were stranded for five days by floodwaters. Conditions were apocalyptic. Deaths were expected.

The aftermath brought uncomfortable revelations. Some bodies contained potentially dangerous levels of morphine and other drugs. The actions of Anna Pou, a doctor at the hospital, were being probed (a grand jury ultimately declined to indict her).

Our knowledge of what happened comes mostly from Sheri Fink, whose award-winning book has now been dramatised in a TV mini-series of the same name.

Five Days at Memorial streamlines the stories included in Fink's account, so there is time to flesh out key characters, such as Emmett Everett, a patient with paraplegia. He was one of several whose care may have been badly affected by ingrained attitudes to weight and disability.

The series' linear structure is its biggest asset, in that it helps to recreate the experience of working in the hospital during the crisis. Dread creeps up on you as you hear the growing thunder of water and witness the failure of back-up generators. Like those at the hospital, you feel abandoned.

But by mostly prioritising the perspectives of Memorial's staff over the patients, a one-sided portrayal emerges. In Fink's account, the horrific conditions are dovetailed with glimpses of the investigation into Pou and nuanced precis of the ethical arguments around euthanasia.

> **"Dread creeps up on you as you hear the growing thunder of water and witness the failure of generators"**

On the whole, the first five episodes do a good job of detailing the failures that led to catastrophe. Memorial had no emergency plan for flooding during a hurricane, for example. Aid teams elsewhere in New Orleans sat idle for hours and the hospital was inexplicably moved down the priority list for evacuation.

Throughout, we are drip-fed falsehoods that underpinned key decisions by staff at Memorial, only to see them debunked. On the final day of evacuations, for instance, many believed the hospital was running out of food and water, but investigation teams would later find healthy supplies.

All too often, however, the show makes changes to the book that affect the truth. Some seem innocuous, like the decision to make one patient, Elvira LeBlanc, barely conscious when her son arrives to rescue her. In reality, her voice was "stentorian", Fink wrote.

Details of missed opportunities to help patients are also left out, such as when a cancer institute connected to the hospital that had electricity and a working generator was used by executives to take phone calls and make coffee, rather than as a hub for patient care.

Worse, the series doesn't include more recent allegations, including one doctor's claim that he smothered a patient.

For the many viewers who have not read Fink's book, the show provides food for thought about how to manage the crises that we are increasingly likely to face as climate change bites deeper. But it is galling that the show takes simple truths from Fink (Katrina was horrific, the people of New Orleans were failed), and removes nuance. It adds little to diligent reporting: not only does it fail to fully convey how we got here, it fails to appear truly interested in the question. ▮

Bethan also recommends...

TV

Dopesick

Disney+

A punishing account of the US opioid addiction epidemic that excoriates Purdue Pharma, the maker of painkiller OxyContin.

The Staircase

HBO

This dramatisation of Jean-Xavier de Lestrade's hit true-crime documentary casts a new light on a familiar story via its critique of one editor's personal conduct.

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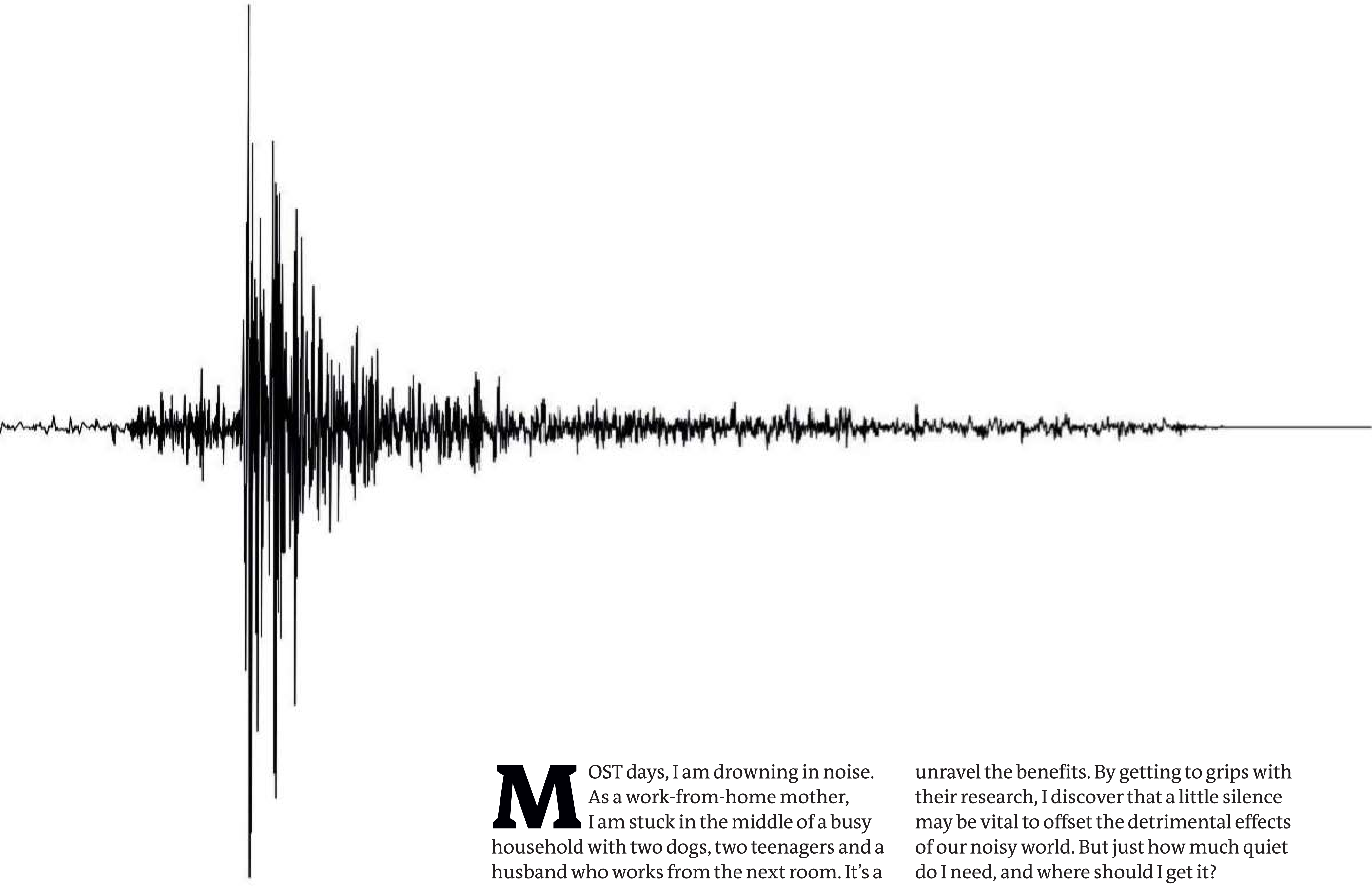


ARCHIVECTOR/GETTY IMAGES

MOST days, I am drowning in noise. As a work-from-home mother, I am stuck in the middle of a busy household with two dogs, two teenagers and a husband who works from the next room. It's a cacophony of Zoom calls, phone notifications, video games, music and barking, and that's before my neighbour starts up his leaf blower.

Is it any wonder I long for some silence? The World Health Organization backs me up – it says that our world is too noisy and that this is harming our health. Of course, for centuries we have known the importance of quietness: in many religions, silence is promoted as a vital healing process. But my noisy surroundings got me wondering what benefits there are to seeking silence in the modern age.

These days, people go in search of quiet in all sorts of places. They join monasteries for a silent retreat or head to the hills for a weekend's peace. There is even an increasing trend for spending time in sensory deprivation or flotation tanks – if you can afford it. Indeed, in his book *Silence: In the age of noise*, Norwegian explorer Erling Kagge calls silence "the new luxury".

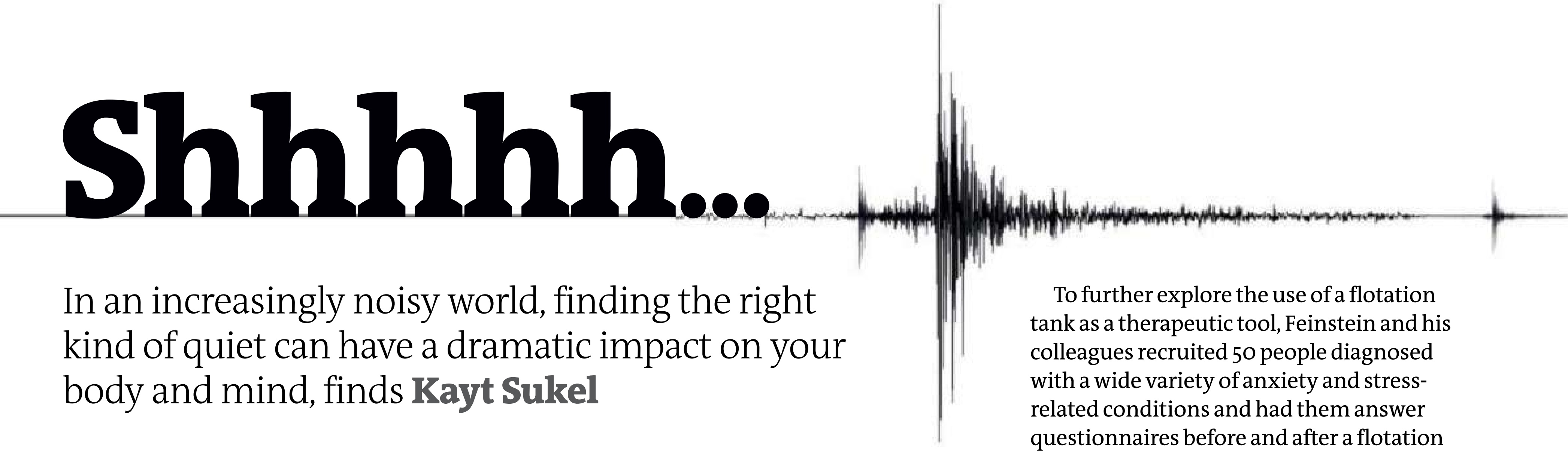
Figuring out what peace and quiet actually does for our mental and physical health is the ambition of a group of neuroscientists and health professionals who are beginning to unravel the benefits. By getting to grips with their research, I discover that a little silence may be vital to offset the detrimental effects of our noisy world. But just how much quiet do I need, and where should I get it?

Float away

First, it isn't just loud in my house. Many of us are living in environments that are too noisy (see "Silence in the city", page 40). We are finely attuned to noise, and for good reason. From an evolutionary perspective, sounds give us vital information, helping us to better navigate the world and avoid danger. To help ensure that loud or unexpected noises get the attention they deserve, our internal chemistry changes in response to them. Our blood pressure goes up, our muscles tense and our body releases stress hormones that prepare us for what is coming next. In the short term, this is a good thing. It helps us fight or fly. When we are exposed to excessive noise over the long term, however, those sustained physiological responses can lead to health problems, from anxiety and depression to cardiovascular disease.

In 2018, the World Health Organization designated noise as an "underestimated threat" to public health, and a 2020 report from the European Environment Agency

Shhhhh...



In an increasingly noisy world, finding the right kind of quiet can have a dramatic impact on your body and mind, finds **Kayt Sukel**

concluded that noise was an ongoing and widespread problem in Europe, with at least 1 in 5 people consistently exposed to levels considered harmful to health.

The good news is that researchers are hard at work trying to find a solution. Alongside making our environments quieter, they are seeking to understand what aspects of silent experiences are most beneficial and how we can best achieve results (See "How to be silent", right).

After my friend told me that a 1-hour float in a sensory deprivation tank gave her a new lease of life, I decided to begin with this. Flotation tanks have been around since the 1950s, when researchers Jay Shurley and John Lilly built the first of these environments to study how the human brain responds to a lack of external sensory input. The design of the tanks has since evolved, with higher ceilings and wider pools so people can get the benefits of a reduced sensory environment without feeling claustrophobic.

After stripping off and entering a small, enclosed pod filled with salty water, I find it is very quiet – but not silent. I am aware of the sound of my breathing.

The human ear is exquisitely sensitive to noise, says Justin Feinstein, a clinical neuropsychologist and director of the Float Clinic and Research Center at the Laureate Institute for Brain Research in Tulsa, Oklahoma. "In these tanks, some people can even hear the sound of their eyes blinking."

But it is that ability to focus on your breath or heartbeat that helps people more easily reach a relaxed or meditative state, says Feinstein. Meditation has a whole host of known health benefits, including reducing stress, promoting a sense of greater well-being and offering relief from chronic pain and migraines.

How to be silent

Make sure you want to be silent. In tests, intentionality appears key to health benefits.

Just a few minutes of regular silence is more beneficial to your stress response than longer periods less often.

Silence taken in a natural setting with a guided relaxation technique brings the biggest gains to health.

Reduce your night-time noise to under 40 decibels to promote better health.

To further explore the use of a flotation tank as a therapeutic tool, Feinstein and his colleagues recruited 50 people diagnosed with a wide variety of anxiety and stress-related conditions and had them answer questionnaires before and after a flotation session. The participants reported decreases in stress, muscle tension, pain and symptoms of depression after a single, 1-hour float. Post-float measures also showed a significant increase in feelings of relaxation along with overall well-being.

"People who are chronically anxious or depressed are always ruminating, cogitating over what is happening – but when they can focus on their breathing and heartbeat in a float environment, they find a lot of their anxious thoughts dissipate," says Feinstein. "These positive effects can last up to 48 hours."

Tal Dotan Ben-Soussan, director of the Research Institute for Neuroscience, Education and Didactics at the Patrizio Paoletti Foundation in Rome, Italy, says these findings aren't surprising. Silence, both inside and outside a flotation tank, can help people more easily get into the kind of meditative state that can promote healing and well-being, she says. "When we find ways to be quiet, we are not only quiet in our environment, but quiet in our inner selves. This allows us to be more aware of what is happening around us and what the situation may require from us so we can provide [a more] adequate response."

While research hints that silencing most forms of external sensation through flotation therapy can elicit short-term reductions in anxiety, depression and pain, less is known about what effects it can have on the brain. To investigate, Feinstein and his colleagues got 48 people to participate in either three 90-minute float sessions or three 90-minute

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periods of relaxing on a reclining chair, spread over a period of three weeks. Each participant had their brain scanned using functional magnetic resonance imaging at the beginning and end of the trial. Float sessions uniquely decreased activity in the default mode network (DMN), a collection of brain regions that are active when the brain is at rest or not engaged in a particular task.

It might seem counter-intuitive that the areas normally more active when the brain is at rest decreased in activity in a float tank, but Feinstein has an explanation. The DMN is closely linked to our internal mind chatter, he says. These areas of the brain that come to life when the brain is at rest are involved in rumination, stress and anxiety.

In a float tank, these areas reduce in activity, suggesting that it is helping you to avoid this internal chatter. Similar decreases in DMN activity are often seen in altered states of consciousness and during psychedelic experiences, which have been linked to improvements in various mental health conditions, including alcohol misuse and obsessive-compulsive disorder. In contrast, excessive DMN activity is commonly linked with depression. Feinstein says it is an exciting finding, because float tanks seem to offer an easy way of "resetting" our nervous system to prevent it from getting out of balance.

When I booked my own float, I invited my husband, who declined, stating: "Isn't that a form of torture?" Certainly, common wisdom would tell you that silence isn't always golden. The earliest studies of sensory deprivation are rife with people who panicked and experienced hallucinations. "Some of the older sensory deprivation experiments basically mummified people," says Feinstein. "The early tanks looked like coffins. Sometimes you wore helmets that had air tubes coming in and out of them. These set-ups would [upset] the average person, let alone someone who was dealing with anxiety."

If you are thinking of using a modern flotation tank, you may experience altered perception, but this tends to involve benign visual auras or subtle humming sounds. "When you don't have external sensory stimuli coming in, the brain tries to fill the void to make sense of this dark and silent

Silence in the city

It's official. The world is getting louder. The World Health Organization says that people living in cities like Mumbai, New York, Paris, Tokyo and Buenos Aires are being exposed to far more than the recommended 40 decibels (dB) of noise at night.

For comparison, 20 dB is similar to the rustling of leaves. A quiet rural area tends to clock in at 30 dB, while restaurant conversation is 60 dB and a lawnmower is 90 dB. Anything louder than 85 dB for extended periods can cause permanent hearing loss. Over time, however, regular noise over 50 dB is linked to a multitude of health issues, ranging from sleep disturbance to problems learning and even cardiovascular disease. "There are no 'earlids' that can protect your brain from noise," says Nick Antonio, an acoustic consultant who has contributed to the British and international standards for noise.

Several cities are working to turn the volume down. In 2004, the office of the mayor of London published a report called *Sounder City*. The strategy highlighted issues surrounding both industrial and transport-related noise, and how to manage it. "London is a quieter city because of those efforts," says Antonio. "By providing recommendations for quieter buses, reducing noise from roads and also controlling noise from aircraft, they were able to make the city quieter."

Other cities are taking note – introducing noise-reducing road coatings, for instance, alongside greenery that muffles sound. Some solutions are more specific: Washington DC's ban on petrol-powered leaf blowers came into effect this year, while San Francisco has instituted quiet hours, with excessive noise prohibited between 10pm and 7am in residential areas. In New York City, legislation was recently approved to fine people who modify their vehicles to make them noisier.

Antonio says the covid-19 pandemic led to quieter streets, with some roads being handed over for use by pedestrians and restaurants. "People are seeing the benefits of these more quiet environments in their cities," he says. "I expect we will see much more of this in the future."

A flotation tank, and (from far left) a silent retreat in Maryland, and Tokyo, Japan

world," says Feinstein.

But what about other kinds of silence? Can they be overwhelming too? Certainly, it is known that the average person can't stay in an anechoic chamber – designed to lock out all sound from the outside world – for more than 15 minutes without feeling very uncomfortable. Yet even sitting in a quiet environment can be difficult for some. In a famous series of studies in 2014, led by Timothy Wilson at the University of Virginia, researchers found that participants would rather give themselves a painful electric shock than sit quietly with their thoughts – suggesting people prefer some stimulation over being left in silence, even if that stimulation is negative.

However, when Eric Pfeifer, a psychotherapy researcher at the Catholic University of Applied Sciences Freiburg in Germany and his colleagues replicated those studies in 2019, they found the opposite effect. "The participants in our study thought it was great. They enjoyed being alone in a room without a mobile phone or laptop," he says. Pfeifer believes it might be that today's participants are more familiar with meditation, yoga and silent experiences, so appreciate the quiet more. Yet he concedes that there are some people who won't benefit from silence, particularly those who are in a heightened state of stress.

"People in these states may not be able to relax or calm down in a silent condition," he says. Professional guidance can help, he adds, allowing people to approach silence slowly so that they can gradually enjoy the benefits.

To date, there are no studies that can predict who will benefit most from silence. Studies looking at traits like impulsivity or self-awareness reveal that these don't seem to affect the ability of silence to improve mood and increase relaxation. Even if you are quite impulsive or have difficulty getting into a meditative state, people still report a positive experience. But when it comes to reaping the benefits, Ben-Soussan says one characteristic is key: you need to want to engage in the silent experience. "We see from animal models and human studies that volition and intentionality is important," she says. "When people do not want silence, it can be very distressing."

Five minutes' peace

Although I did feel more relaxed after my float, I wondered whether it was necessary. Would other kinds of near-silence, like a walk up a hill or a moment's peace in my bathroom, also boost my health? For that answer, I turned to Pfeifer and his colleagues, who have been studying different types of silence and their potential benefits. Pfeifer's group compared different types of silent experience with one another. The tests included up to 15 minutes of silence experienced alone, or in a group, inside and outside, with instruction or without, paired with occasional episodes of relaxing music or without.

All types of silence led to improved mood and increased relaxation in the majority of participants. But some were better than others. Periods of silence in a natural setting like a park, when combined with a therapist to guide them with intermittent relaxing music or meditation, offered the best results.

This suggests I may need to invest a bit of time and money into seeking the best kind of quiet. But Pfeifer is convinced that silence is more attainable in everyday life than people think. First, complete silence isn't necessary. In a recent study by Pfeifer and his colleagues, participants reported more relaxation and less boredom when they sat quietly in an outdoor garden compared with a completely silent room. Meredith Berry at the University of Florida in Gainesville says that converging evidence shows we can benefit any time we quiet things down, whether it is through silence, meditation or a walk in the woods.

Second, Pfeifer says that we don't need a lot of silence to gain benefits. His studies report improvements to relaxation and stress relief in sessions that last less than 10 minutes, so he believes that even a few minutes' peace in a bathroom can be helpful in managing physiological responses to our noisy world.

"You don't need to spend hours in silence to see benefits," he says. "It is likely better to have more frequency of silence for a few minutes at a time than a longer period of silence only once a week. We are so overstimulated by sound that just finding those places in your daily life where you can find some silence and trying to emphasise those can make a big difference."

He doesn't have to tell me twice. Even though I probably can't fit a regular float into my week, I can certainly find a few moments each day for more silence, even if it's in the bathroom. It's the kind of luxury that is worth the investment. ▮

Kayt Sukel is a science journalist based in Texas

FROM TOP LEFT: MARK GAIL/THE WASHINGTON POST VIA GETTY IMAGES; DIDIER MARTI/GETTY IMAGES; DIDIER MARTI/ALAMY

The universe by numbers

A handful of bizarre, mind-blowing figures, whether exceedingly big or unfathomably small, reveal the universe's greatest secrets, says **Antonio Padilla**

CHRISTIAN GRALINGEN

IT CAN often feel like our days are governed by numbers in the most mundane ways. They tell you that you are going to be late for work, how much interest you are paying on your mortgage and how old you will be when you finally pay it off. But numbers can also be exhilarating. For me, as a cosmologist, the most fantastic numbers have meaning far beyond the scope of our humdrum daily lives. Some are indescribably small, others incomprehensibly large. What unites them is that they can reveal the secrets of how the universe works, and – most excitingly – the deep and meaningful mysteries that continue to confound physicists today. Here are five of the best.

10^{-120}

To appreciate how small this number is, imagine shrinking a person to the size of a proton, and then again by the same ratio, and again, a total of eight times. The miniature human left would now be 10^{-120} times its original size. This is many orders of magnitude smaller than the Planck length, a fundamental unit of distance at which space, in the classical sense, ceases to make sense.

In nature, exponentially small or large ratios between sizes are rare, and when they happen, physicists are hardwired to seek an explanation. Of course, there are no humans 10^{-120} times the size of a typical person, but this minuscule number does appear when we compare observations to our best and most well-tested theory of the universe: quantum field theory. More specifically, it crops up when we start thinking about vacuum energy – the energy of empty space and the driving force of cosmic expansion. This means understanding this tiny ratio is one of the greatest outstanding problems in fundamental physics.

Our universe is expanding, the space between distant galaxies growing larger over time, and this process is speeding up. It is generally agreed that this acceleration could be the result of the underlying energy of empty space – energy it gets from virtual particles popping in and out of the vacuum, called vacuum energy. Virtual particles aren't particles like an electron or a proton that you can see in an experiment. They are a convenient way to imagine ambient quantum fields that push and pull on every particle in the universe, and even on space itself. We know these fields exist because we see their effects in experiments. They should also give the universe a vacuum energy.

Problems start when we calculate how much vacuum energy there is. Based on our current understanding of quantum field theory, the energy density of the vacuum should be enormous. A coffee cup of empty

"A universe with the vacuum energy we predict would be bent into oblivion"

space should have enough energy to blow up every planet in the observable universe more than a trillion trillion trillion trillion times. But this isn't the case – and for that, we should be grateful, because a universe with this much vacuum energy would be bent into oblivion by gravity. According to the gentle acceleration of the universe's expansion that we measure with our telescopes, the vacuum energy is actually hundreds of orders of magnitude less than our models predict. In other words, it is 10^{-120} times the value predicted by quantum field theory.

So what gives? A possible answer is that there is something wrong with quantum field theory. Unlikely, since this theory is the most accurately tested in all of physics. Alternatively, we might think there is something missing from Albert Einstein's theory of gravity – after all, it is only through gravity that we could ever feel the true vacuum energy. The trouble is that Einstein's theory is also very robust: change it too much and you can unleash all manner of instabilities and mathematical catastrophes.

Some physicists have argued that, out of all the possible universes, one with a tiny value for the vacuum energy is necessary for complex life to have evolved. Such an explanation requires physics to conjure up a multiverse, a vast, traversable landscape of different universes with different particles, properties and laws. At least one universe in the multiverse should look like our own. However, we still don't have a complete description of a multiverse in any of our fundamental theories.

Can experiments help us find an answer? Up until now, not really. The only experimental probe we have had has been through the accelerated expansion of the universe. But, along with colleagues in Nottingham, UK, as well as in London and L'Aquila, Italy, I am now studying the gravitational properties of vacuum energy directly.

It turns out that the core of a neutron star, the densest type of star in the universe, could be so dense that it triggers a change in the vacuum energy. This could leave an imprint on the size and shape of the neutron star, something we could try to detect with gravitational waves, ripples in space and time that were first

›

Infinity

The biggest number of all. The number that goes on forever. In maths, there are multiple infinities: there is the infinity that counts the whole numbers and the squares, but also higher infinities that count larger sets, like the set of real numbers between 0 and 1. In physics, too, infinities take us to the limits of our knowledge.

If we venture into the deepest innards of a black hole, say, or rewind to the moment the universe was born, we are confronted with what we call a "singularity". This is a region where the gravitational field becomes infinitely strong. In Albert Einstein's general theory of relativity, gravity is understood to be the warping of space-time, with planets following curved paths in the distorted space-time around the sun because it is the most efficient way to traverse the geometry that exists there. At a singularity, that warping in space-time blows up to infinity, and Einstein's law can no longer describe what is going on.

To grasp these singularities, we need a theory capable of describing the strongest and most violent gravitational fields and all the matter that interacts with them. In other words, we need a theory that explains all aspects of the universe.

In my opinion, the most compelling candidate for this is string theory. In it, all the particles of nature are understood to be made up of tiny vibrating one-dimensional entities known as strings. Unlike some of its rivals, we can perform reliable calculations in string theory, and make the infinities disappear. The transition from particles to strings means we no longer need to worry about particles interacting with one another over infinitesimally small distances.

Those tiny distances were responsible for the infinities that broke our equations, so now they can be vanquished. Quite how this plays out for the singularities at the core of a black hole, or at the moment of creation, we don't yet know. But once we figure out how to do the maths for them, we should be able to understand the creation of our universe.

detected in 2015. The hope is that through probing some of the most exotic objects in existence, we can finally understand one of the smallest numbers in the universe.

0.000000000000001

This next number, relative to the previous one, is colossal. And yet to us, it is still imperceptibly tiny. If you scaled a human down by this amount, they would be a million times smaller than the width of an atom and 10 times smaller than a proton. Just like our first number, this tiny figure expresses a ratio between what we actually see and what our best theories predict. In this case, it is related to the Higgs boson.

When the discovery of this particle was announced on 4 July 2012, it was said to be the crowning glory of the standard model of particle physics, which accurately describes the microscopic dance of all the visible matter in our universe. The Higgs was the final piece of this particle jigsaw, explaining why fundamental particles, including the Higgs boson, have mass. But we knew that something was up with some of the numbers involved. In fact, there was something up with the mass of the Higgs boson itself.

Like all particles, the Higgs is pushed and pulled by the ambient quantum fields I mentioned earlier – the ones that permeate all of space. I think of these fields like a quantum fluid that surrounds the particle, from which it can never escape. This fluid drags on the Higgs, increasing its inertia, or, in other words, increasing its mass. When we calculate how much mass the Higgs should have, we find that it ought to weigh a few micrograms, about the same as a tiny wasp known as a fairyfly. In reality, when it has been measured again and again, the Higgs boson is 1000 trillion times lighter than this. Put another way, it has 0.000000000000001 times the mass we expected.

The unbearable lightness of the Higgs is troubling for particle physicists. Theorists have come up with a few potential explanations, from extra dimensions to doubling up on the number of particles in some theories, drastically changing the properties of the ambient quantum fluid as we push to higher and higher energies. They have even tried breaking the Higgs up into tiny bits – at microscopic scales, it is no longer the Higgs that interacts with the quantum fields, but its constituent particles, and they could do so very differently.

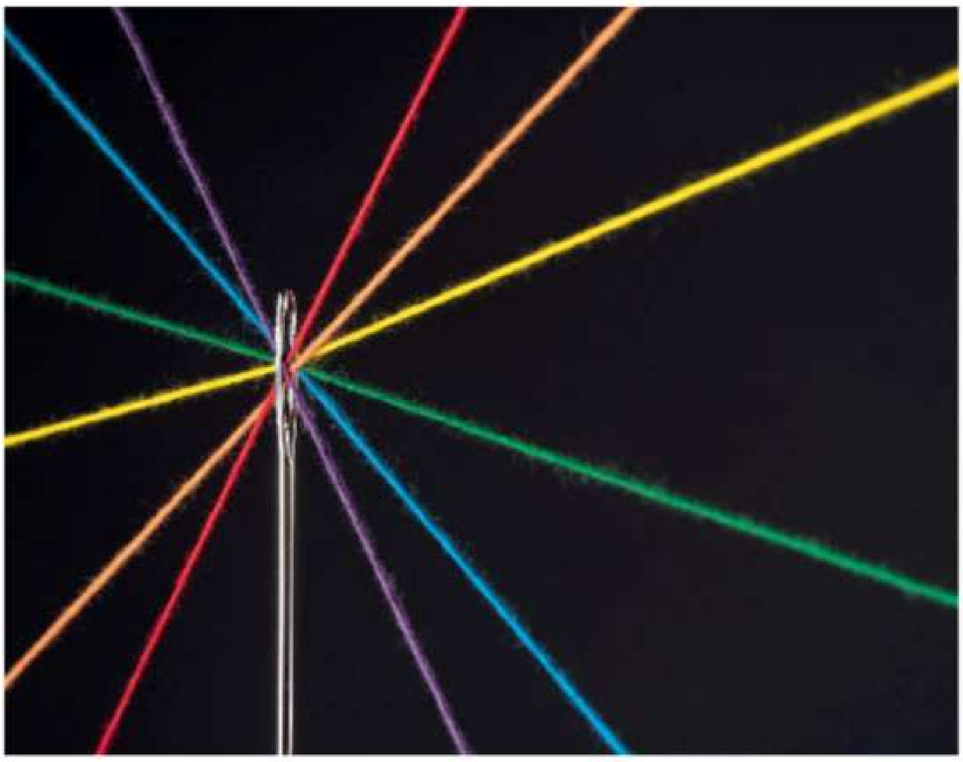
So far, experiments at CERN, the particle physics facility near Geneva, Switzerland, have shown no evidence to support any of these ideas. However, after a three-year hiatus, the Large Hadron Collider (LHC) has just been turned on for a third run, probing collisions with higher energies and greater precision than before. This means CERN may soon finally get some evidence for one of the hypotheses and discover the reason behind the unexpectedly light nature of the Higgs.

10^{80}

Our third number is huge by any standards. If you were to scale a human up by this amount, they would be 10 billion billion billion billion billion billion times bigger than the observable universe. 10^{80} is actually the number of ordinary particles there are in this universe, so we can expect it to be big. What doesn't make sense to a physicist like me, however, is why there are any particles at all.

About 5 per cent of the universe is composed of normal matter – the stuff that makes up you and I and all the things we can see, like stars and galaxies. But it also contains antimatter. Antimatter is rare, so rare that it is generally regarded as the most expensive substance in the universe, costing the equivalent of more than $60 trillion per gram to produce in particle colliders. This strange stuff is like matter in a mirror. In fact, if you wanted to change a particle to its antiparticle, you would have to flip it in all directions of space, as well as its electric charge. This hypothetical transition is known as a charge-parity flip, and it takes a negatively charged electron to a positive charged positron. Under the standard model of particle physics, these "flips" are what is known as a symmetry.

According to this model, because of this symmetry, the big bang should have created an equal amount of matter and antimatter.



Symmetries cause some of the biggest mysteries in particle physics

SUNYIXUN/GETTY IMAGES

But when matter meets antimatter, the two annihilate. In that case, they would have annihilated each other to leave nothing but a bath of boring radiation. But as the fact of our existence demonstrates, that didn't happen – and we don't know why.

One option is that the missing antimatter is out there somewhere, hiding from us. But we should be able to see evidence if that were the case. We might see gamma rays being given off where antimatter meets matter, for example, and we don't. The reality is we need a mechanism that breaks the symmetries in our physical theories that connect matter to antimatter in exactly equal quantities. This would require an extension of the standard model.

The good news is that ideas for how matter came to dominate the universe can be probed by experiments, ranging from collisions at the LHC to gravitational wave observations. One suggestion is that the Higgs can be broken up into smaller bits. They would allow for new particles that break the symmetry between matter and antimatter, and whose interactions with other fundamental particles could be detected in the third LHC run.

These new particles could also have affected how the Higgs started handing out mass to other particles in the primordial soup of the early universe. The precise details of this could be imprinted on an ancient background of gravitational waves, similar to the cosmic background of microwave radiation we see left over from the big bang. The hope is that this gravitational wave background will be discovered by future space-based detectors, such as the Laser Interferometer Space Antenna (LISA), which could launch in the 2030s, revealing clues as to how and why ordinary matter like us managed to avoid annihilation.

$10^{10^{68}}$

Here we have a number so ludicrously large that it is tricky to compare with any other numbers: 10 to the power of 10 to the power of 68 corresponds to 1 followed by 100 million trillion trillion trillion trillion trillion zeroes.

It is a number I have named the doppelgängion, because it relates to the chances of there being another person like you, a doppelgänger, somewhere else in our universe. To be clear, we aren't talking about doppelgängers in other universes disconnected from our own, as imagined in the many worlds interpretation of quantum mechanics, or any other multiverse theory. Instead, we are asking about our very own universe and the possibility that your doppelgänger is out there – same nose, same eyes, even the same thoughts. It is an idea that goes back to physicist Max Tegmark at the Massachusetts Institute of Technology.

It might seem absurd. But ultimately it comes down to the probability that there is another bit of space, the same size as the one you occupy, in exactly the same quantum state, encoding the likely arrangements of all the particles that make up you.

> "Details of particles could be imprinted on ancient gravitational waves"

The thing is, there are only a finite number of quantum states that can describe the volume of space you take up. To compute how many, us cosmologists need to use one of the most remarkable things we have learned about gravity in the past 30 years: it behaves like a hologram, encoding quantum information on the two-dimensional surface of a volume, rather than in the interior. To count the quantum states, you need to imagine the surface that surrounds you, and break it up into the smallest possible building blocks, with dimensions the size of the Planck length. Add up all the different patterns you can generate and you arrive at a doppelgängion.

What this all means is that you are one of a doppelgängion possibilities. So am I, so is a cow and so is a cubic metre of empty space. To appreciate the implications of this, we need to imagine a universe that is far greater than a doppelgängion metres in radius, containing far more than a doppelgängion cubic metres of space. Although the chances of any one cubic metre containing your doppelgänger are very low, if the universe is big enough, you can overwhelm the odds.

Could it be large enough? The observable universe extends to about 47 billion light years, but it doesn't stop there. Measurements of radiation left over from the big bang – the cosmic microwave background – tell us that it is at least 250 times larger than what we can see. A further clue to the true size of the cosmos could lie in that leftover radiation, which reveals that our region of the universe underwent a burst of accelerated expansion very early on, helping it grow big in a very short space of time. These bursts of inflation could have happened anywhere in the universe and at any moment, turning small pockets of space into something more gargantuan.

This allows us to imagine extremely distant worlds – too distant to ever visit, but that are part of the same universe as ours. With the entire universe constantly inflating in one bit of space or another, the idea of a gigantic universe becomes a little less fanciful. If the universe is large enough, your exact copy will be out there, reading an article about fantastic numbers. ■

Antonio Padilla is a cosmologist at the University of Nottingham, UK, and author of *Fantastic Numbers and Where to Find Them*

KYLE ELLINGSON

Earth's infancy

A picture of the early evolution of our planet is starting to emerge, and it throws new light on the origins of life, finds **Michael Marshall**

EARTH is 4.5 billion years old. It formed at the same time as the sun and the other planets in our solar system when thousands of rocks, large and small, collided and merged. Then came a hammer blow. A smaller planet seems to have struck Earth with such force that our world's entire surface melted and huge amounts of material were blasted into orbit, eventually forming the moon. This explains why Earth's first 500 million years are called the Hadean aeon after the mythical Greek underworld. But eventually, the vast sea of hot magma cooled and solidified into rock. Oceans formed. Land masses emerged.

The young planet would still have looked profoundly different from today. There was no oxygen in the air, so lots of metallic iron was dissolved in the water, staining the oceans green. Levels of atmospheric methane were perhaps high enough to colour the sky orange. And any land would have been barren rock, mostly dark black and grey.

How this otherworldly landscape came into being has long been a mystery. When did the oceans emerge? How deep were they? Was there always exposed land above the waves, or was Earth once a true water world? Now, a sketchy picture is starting to emerge. It doesn't just reveal surprises about the making of our planet. Understanding when Earth first got dry land also shapes ideas about how life began. Some scenarios for its origin require exposed surfaces, so they can't be true if everything was underwater. The question of Earth's first land is therefore also a question about the origins of every living thing, including us.

There are almost as many hypotheses about the origin of life as there are scientists thinking about it. One much-discussed idea is that life began in alkaline vents on the seabed, where warm, chemical-rich water flows up into the ocean from deep inside Earth. This fits with evidence that the earliest microorganisms fed off chemical energy. But many chemists doubt that the building blocks of life, including amino acids and nucleic acids, could form in such places. A second school of thought holds that life emerged on land in a pool or pond. Experiments reveal that many key biomolecules can form in such a setting, often driven by cycles of wetting and drying. However, critics say the chemical reactions used in these studies throw up a problem, as they often require highly reactive substances that kill living organisms. Furthermore, supporters of the vent hypothesis sometimes argue that the pool hypothesis can't be true because there was no dry land on the young Earth. Yet that depends on when life emerged, which is also much contested.

The geological record gets increasingly spotty the further back in time you go. There are no rocks preserved from the Hadean and few from the next aeon, the Archean, which ran from 4 billion to 2.5 billion years ago. Nevertheless, there is confirmed evidence of microorganisms from 3.5 billion years ago preserved in rocks at Pilbara in Australia. In 2017, researchers led by Martin Van Kranendonk at the University of New South Wales in Sydney, Australia, reported that these microbes lived in and around hot springs on land. Not everyone agrees with this interpretation, but there is undisputed evidence of microbes on land from 3.2 billion years ago. This comes from rocks in South Africa that record an estuary environment, complete with wind-blown sand dunes.

Still, this leaves a gap of at least a billion years from when Earth formed. In theory, life could have originated in a world-spanning ocean over 4 billion years ago: there is certainly no shortage of claims of earlier evidence of life. If so, say proponents of this view, whenever the first land emerged it was promptly colonised from the sea. But it is also possible that land formed much earlier than 3.5 billion years ago and that life originated there, not in a primordial ocean.

The sparse geological record makes these opposing ideas difficult to test. Until fairly recently, it was thought that the Hadean magma ocean lasted a long time, perhaps 500 million years. But two studies published in 2001 challenged this view. Both analysed zircons, tiny crystals that form in certain kinds of molten rock, whose chemical make-up holds clues about the environment where they formed. Researchers examined zircons from the Jack Hills in Australia, some of which were 4.3 billion years old. One solitary crystal was even more ancient: 4.4 billion years old. Yet all of them had a characteristic mix of different kinds of oxygen atoms, suggesting › the rock from which they formed was interacting with liquid water. Later analyses indicated that Earth's magma ocean had solidified earlier than 4.4 billion years ago. It would appear that the Hadean aeon wasn't as hellish as was previously assumed.

The zircon findings have been taken to mean Earth had oceans 4.4 billion years ago, barely 100 million years after the planet formed. Van Kranendonk says that is unwarranted: "There does seem to be water-rock interaction, but you get water in magmas all the time, that's not unusual. It doesn't necessarily mean it's the oceans." He suspects the young Earth was still on the hot side, so instead of oceans of liquid water, there was a lot of steam and water vapour in the air. Still, oceans seem to have appeared earlier than we thought. Zircons show a shift in oxygen atom types around 4.2 billion years ago, which Van Kranendonk says marks the formation of large oceans.

Water world

Where all this water came from isn't entirely clear. One idea is that the rocks that formed Earth contained water, which subsequently welled up to the surface. Alternatively, the newborn planet may have been dry and only received water later from incoming comets and asteroids. A third possibility is that the water came from deep space and was caught in Earth's gravity. The debate continues, but what is clear is that water was plentiful from early on.

Whether this water took the form of a surface ocean or sank into Earth's interior is another question – one that Junjie Dong at Harvard University and his colleagues set out to answer in 2021. They compiled data on the amount of water that could be stored in rocks found in Earth's mantle, the thick layer beneath the crust. It turned out that hot mantle rocks can't carry as much water as when they are cooler. Earth's interior was hotter just after it formed, so the young planet couldn't store as much water in its interior as it does now. Today's mantle has the potential to hold 2.3 times the mass of the ocean, but in the Hadean and early Archean, it could probably only hold 0.7 ocean masses. That means some of the water that is currently inside Earth must have been on the surface when the planet was young. Dong estimates that the early ocean may have been as much as four times the volume it is today.

During the Hadean, "it's possible the Earth was flooded with water, with almost no or little land", says Dong. To at least some extent, this was carried through into the Archean. He points out that most of the rocks preserved from the early Archean don't look like they came from dry land. "A lot of those rocks were formed under the water," he says. Still, not much land doesn't mean no land. After all, the Pilbara microbes seemingly lived on land 3.5 billion years ago. And there is even older evidence of land from the Isua Greenstone Belt in south-west Greenland, which contains rocks that are 3.7 billion years old. Most of them formed underwater, but some sections appear to be the remains of volcanic island chains.

The difficulty is that there are very few rocks from the early Archean, so if land was scarce, we shouldn't necessarily expect to find any preserved. However, in recent years, geologists have found other lines of evidence. One was in a study published in February by researchers led by Desiree Roerdink at the University of Bergen in Norway. They looked at rocks called barites found in southern Africa, India and Australia, that formed between 3.5 billion and 3.2 billion years ago in the middle of the Archean. Barites contain two versions of the element strontium. One type is more common in oceanic crust, the other in continental crust. By measuring how much of each is preserved in the rock, the team determined whether the seas were receiving sediments from the continents as a result of weathering by natural processes such as wind – and thus whether large land masses existed.

Roerdink's team found that chemical weathering of land rocks was gradually increasing between 3.5 billion and 3.2 billion years ago. Extrapolating back to earlier times, they calculated that weathering of land began around 3.7 billion years ago. "We cannot say there was no land before 3.7 billion years ago, but what we can say is that from around that time, weathering of this land started to significantly affect the chemistry of the oceans," she says.

This makes sense in the light of new evidence about what was happening in the young Earth's crust at that time (see "The birth of plate tectonics", page 49). As the planet cooled, its crust formed into the sort of large, mobile plates that we see today. If these tectonic plates started jostling around and bashing into one another some 3.8 billion years ago, that would explain why Roerdink's team found evidence of significant land masses shortly afterwards,

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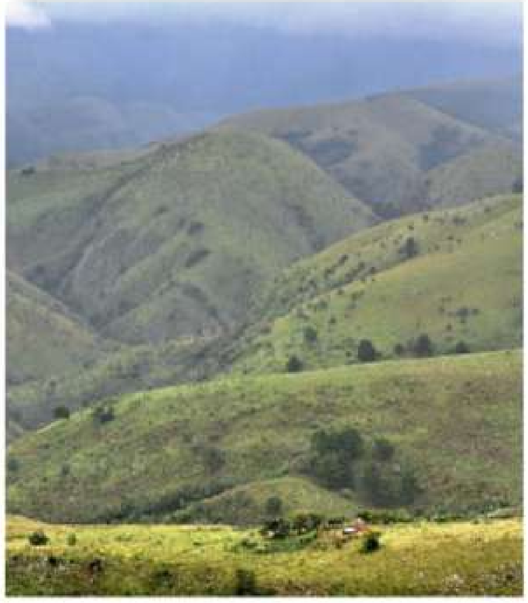

FRIEDRICH VON HORSTEN/ALAMY

Archean rocks in Australia (top) and South Africa (below)

> "The Archean Earth of green seas, orange skies and black rocks may all seem quite alien"

at 3.7 billion years ago.

The researchers also estimated how much land was needed to account for the weathering they observed. Whereas today about 29 per cent of Earth's surface is land, between 3.5 billion and 3.2 billion years ago, it was just 2 to 12 per cent. It took hundreds of millions of years for these early continents to grow to something approaching modern sizes. The first supercontinent probably started forming around 2.7 billion years ago.

Land ahoy

Huge uncertainties remain, but the evidence for when dry land existed has been pushed back a long way. "My feeling is that certainly since 3.7 billion years ago, and probably before that, there have been exposed land masses at the Earth's surface," says Van Kranendonk.

All this points to a tale of three parts in the making of Earth. Early in the Hadean, the molten planet acquired a steamy atmosphere with limited surface water. Then oceans formed and Earth was almost or entirely submerged. Finally, starting in the early Archean, plate tectonics got going so that isolated islands were gradually joined by larger land masses.

What does this mean for the origin of life? It seems that large oceans formed around 4.2 billion years ago, so if life arose in a deep-sea vent it must have been after that. But if life began on land, it could have appeared earlier, when water first started falling onto the surface, as much as 4.4 billion years ago. "As the atmosphere is raining out, then you actually have the whole surface of the planet as a geochemical reactor," says Van Kranendonk. Alternatively, life could have emerged later, on volcanic islands, which probably existed 3.7 billion years ago and perhaps earlier.

Although we still can't pinpoint the time or place of life's origins, we do now have a much better picture of the early life of our home planet. From steamy magma blob, to water world, to the Archean Earth of green seas, orange skies and black rocks, it may all seem quite alien. But Van Kranendonk doesn't see it that way. Within a billion years, there was already a lot that we would find familiar, from the vast oceans to the land masses dotted with volcanoes and hot springs, he says. "From my perspective, I feel like I can recognise early Earth." ▮

The birth of plate tectonics

Today, Earth's crust is divided into several dozen large tectonic plates, which move around at speeds that are imperceptible to the naked eye. Over millions of years, the plates change positions and continents are carried from place to place. When plates push against one another, one may be forced down or "subducted" into the mantle.

The newly formed Earth was too hot for the crust to form into rigid plates. "The mantle might have been too hot and the crust too buoyant and too squishy," says Nadja Drabon at Harvard University. What happened instead is much debated. One possibility is that Earth developed a "stagnant lid": the crust became divided into plates, but they rarely or never got subducted. Alternatively, material may have accumulated on the underside of the crust and dripped off into the mantle when it got too heavy – a process called sagduction.

Estimates of when "modern" plate tectonics got started vary wildly – from 4 billion years ago to less than 1 billion years ago. "That's a huge range," says Drabon. In a study published in April, she and her team tried to pinpoint when the plates started moving. They studied the chemical make-up of South African zircons from between 3.3 billion and 4.1 billion years ago. Chemicals in these tiny crystals hold clues about the rocks they formed in, and the team found evidence of a significant shift around 3.8 billion years ago. Older zircons were formed in very long-lived crust, suggesting little or no subduction was happening. But younger zircons carried evidence of short-lived crust, indicating that tectonic plates were moving and being recycled. This may or may not have been true subduction, but Drabon calls it "the first step toward the system that we have today".

Other researchers have found unambiguous evidence of subduction, but rather later, around 3.2 billion or 3 billion years ago. It may be that there were isolated instances of subduction and other modern-like activity early on, perhaps partly triggered by asteroid impacts, with global mobile tectonics only taking hold later.

GREG BALFOUR EVANS/ALAMY

Life may have originated on land in pools similar to Hell's Gate in New Zealand

Michael Marshall is a science writer based in Devon, UK, and author of *The Genesis Quest*

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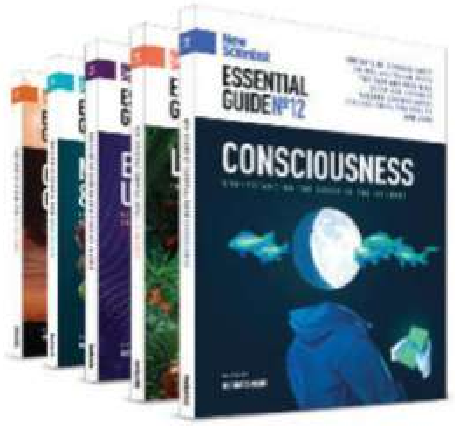


The back pages

Puzzles
Try our crossword, quick quiz and logic puzzle p53

***Almost* the last word**
Does an electric car weigh more after being charged? p54

Tom Gauld for *New Scientist*
A cartoonist's take on the world p55

Feedback
A mummy in the attic and jellyfish crisps: the week in weird p56

Twisteddoodles for *New Scientist*
Picturing the lighter side of life p56

Stargazing at home

Tip me up and pour me out

Look out for the Teapot, a group of stars that looks as if it has the steam of the Milky Way coming out of its spout, says **Abigail Beall**

Abigail Beall is a feature editor at *New Scientist* and author of *The Art of Urban Astronomy* @abbybeall

What you need

Dark skies
A bit of imagination

ONE of the highlights of stargazing at this time of year is finding a dark enough spot to see the majestic bulge of the Milky Way. From March to September, we are in the perfect position to observe our galaxy's dense core of stars, which appears as a band of light across the sky.

ALAN DYER/VWPICS/ALAMY

Another treat in the sky at the moment is the Teapot. This asterism, a collection of stars that isn't a formal constellation, is one of the most recognisable patterns seen in the sky right now. In the northern hemisphere, it sits in the perfect spot for the band of the Milky Way to look like steam coming out of the Teapot's spout. In the southern hemisphere, the Teapot is still visible but appears upside down.

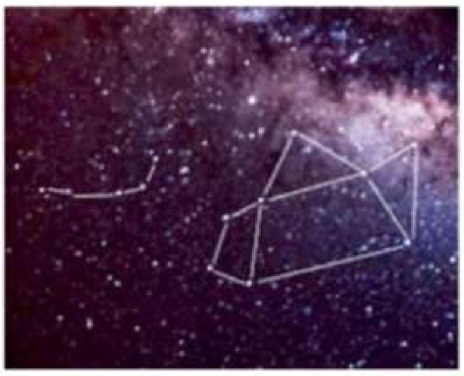
Located in the constellation of Sagittarius, it is much easier to spot the Teapot alone than to see the larger pattern of its parent constellation. It also points us towards an exciting part of the sky.

To find the Teapot, we can use the planet Saturn, which will be visible in August and September after the sun has set. Saturn will be in the south-eastern sky in both hemispheres. It will be brighter than the stars around it and you will be able to tell it is a planet because its light won't flicker.

Then, we will need to find the bright star Antares, part of the constellation of Scorpius. In the northern hemisphere, look to the south-western horizon just after sunset and the brightest star you will see there is Antares. In the southern hemisphere, Antares will be found directly overhead. Whichever hemisphere you are in, look between Antares and Saturn, and you will find the Teapot.

To make things easier, you could wait until 5 September, when the moon will appear to be inside the Teapot. If your skies are dark enough, you will be able to spot the steam of the Milky Way making its iconic arc across the sky, stretching out from the opening of the Teapot's spout.

You may also spot the Spoon, an asterism that hovers next to the Teapot, on the same side as Saturn. Also situated in Sagittarius, it sits next to the brightest part of the Milky Way's arc and looks like a small, curved line.



Abigail's annotated photo of the Teapot in June 2018

The Teapot is next to the centre of the Milky Way, so if you find it then you are looking at the heart of our galaxy. This is where the supermassive black hole Sagittarius A*, which we were treated to the first ever direct image of earlier this year, is found.

Because it is at the dense centre of the galaxy, the Teapot is a great place to look at through binoculars or a small telescope. At the top of its "lid" is a spherical grouping of stars – a globular cluster – called M22, visible to the naked eye in dark enough skies, but clearer through a telescope. On a dark night, though, studying this part of the sky with the naked eye will still reveal a host of wonders. ▮

These articles are posted each week at newscientist.com/maker

Stargazing at home appears every four weeks

Next week

Science of gardening

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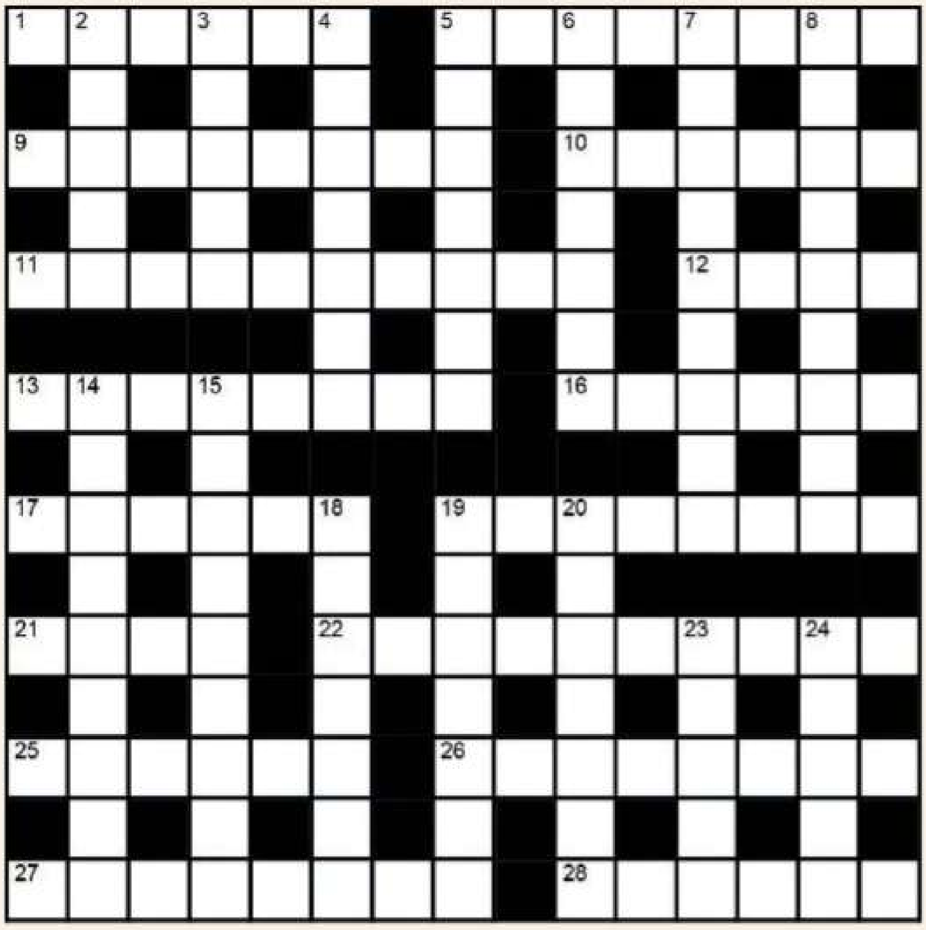
Quick crossword #114 *Set by Richard Smyth*



Scribble zone

Answers and the next cryptic crossword next week

ACROSS

1 Soft covering of an undeveloped antler (6)
5 Harmful bacteria often consumed in contaminated food (8)
9/18 Down ___ *Castle*, 1962 novel by Philip K. Dick (3,3,2,3,4)
10 Fatal (6)
11 Fundamental mathematical discipline (10)
12 Appends; attaches (4)
13 American marsupials (8)
16 Fastened with a sturdy metal pin (6)
17 Not in motion (2,4)
19 Suddenly; quickly (2,1,5)
21 Small (prefix) (4)
22 Encoding (10)
25 ___ atoll, Pacific nuclear test site (6)
26 Method of using heat to join two metal surfaces (4,4)
27 Luminescent substance (8)
28 Moon of Jupiter (6)

DOWN

2 CH_3OCH_3, for example (5)
3 Throw up (5)
4 Ground-dwelling New World bird (7)
5 Cough medicine (7)
6 Si (7)
7 Relating to the tidal mouth of a large river (9)
8 Computing network label (2,7)
14 Place of culture? (5,4)
15 Details (9)
18 See 9 Across
19 Cutting tooth (7)
20 Enzyme that catalyses the hydrolysis of starch (7)
23 Minaret; monument; skyscraper (5)
24 European wildflower, *Primula elatior* (5)

Our crosswords are now solvable online
newscientist.com/crosswords

Quick quiz #164

1 Which is the only moon in our solar system known to have a thick atmosphere?

2 Anemophilous plants are pollinated by what means?

3 Which species boasts the largest leg span of any arthropod?

4 Which English clockmaker invented the marine chronometer?

5 How many stable isotopes of oxygen are there?

Answers on page 55

Puzzle

set by Howard Williams

#180 Neat as a PIN

I sometimes have difficulty remembering my five-digit PIN. I am cautious, so I don't want to write it down, and I use five different digits so it isn't easily guessed.

Fortunately, it has a special mathematical property that allows me to work it out if I ever need to.

All I need to remember is that if I add an extra digit to the start of the PIN, it makes a new number that is an exact multiple of the new number created if I add the same digit to the end of the PIN. As it happens, this multiple is also the same number as the extra added digit.

It is enough to defeat most people, but can you work out what my PIN is?

Solution next week

Battery boost

Does my electric vehicle weigh more after I have charged it?

Alex McDowell
London, UK
According to Albert Einstein's theory of special relativity, energy has mass. Through his equation $E = mc^2$, we can deduce the mass of energy put into batteries.

The battery of a large Tesla holds 100 kilowatt hours, or 3.6×10^8 joules, hence the extra mass from charging it would be 4×10^{-9} kilograms. This is small compared with the mass of the car, which is typically more than 2000kg for a large Tesla.

Eric Kvaalen
Les Essarts-le-Roi, France
If you add 100kWh to your battery, or 360 megajoules, according to special relativity ($E = mc^2$), you increase its mass by 4 micrograms – around the mass of a small grain of sand.

When charging a lithium-ion battery, for example, one electrode loses mass and the other one gains it as lithium ions move from one to the other, but the net change in the mass of the battery will be 4 micrograms.

> **"A bit of the increase in mass of a charged electric car is from the stored energy, but most is due to the dust that gathers"**

David Muir
Edinburgh, UK
When a rechargeable battery is being charged, most people understand that a direct electric current is flowing into the battery at the negative electrode.

It is less appreciated that the same current is flowing out of the battery from the positive electrode. There are no more electrons in the battery after charging than there were before. The thing that has increased is the amount of chemical energy that can transform to electrical energy when the battery is discharged.

Spencer Weart
Hastings-on-Hudson, New York, US
Your electric car will weigh less after charging.

No doubt some readers will calculate the gain through $E = mc^2$, but this will be far smaller than the loss from molecules knocked loose when you insert and remove the charging nozzle.

Additionally, a tiny warming in components of the electrical system will probably evaporate some water and other molecules from car surfaces into the air.

Adrian Bowyer
Foxham, Wiltshire, UK
Yes, the mass of the car will increase. A bit of this will be because the stored energy has mass. But most will be due to the dust the car gathered while parked.

Incidentally, all the electricity that humanity generates in a year, around 9×10^{19} joules, has a mass of about 1 tonne – less than half of the total mass of an electric Renault Zoe.

Nick Leach
Watford, Hertfordshire, UK
It is estimated that a person infected with covid-19 contains 1 to 100 micrograms of virus, so the mass gained by charging an electric car, 4 micrograms, is about the same as the mass of covid-19 virus in an infected person. I feel there is a new unit of measurement in here somewhere...

CAVAN IMAGES/ALAMY

Why do some people perceive extra colours below the bottom violet stripe in a rainbow?

This week's new questions

Bow extras **Why, when I see a rainbow, do I perceive two extra colours (yellowish and greenish) directly beneath violet? Am I seeing UV wavelengths, with my brain interpreting them as those colours?** ***Carlo Favetta**, Wyong, New South Wales, Australia*

Eyelash expression **Why do we open our mouths when we put on mascara?** ***Megan Gill**, London, UK*

Fossil afterlife

What would be the best way to fossilise my body after I die? And would an inscribed gold plate with my epitaph survive a few million years in rock, in case a future archaeologist finds my fossil?

Pat French
Rockhurst, Shropshire, UK
To turn yourself into a fossil, your burial site needs to be located where you won't rot away – typically somewhere anaerobic, such as a peat bog or tar pit.

Then, you must arrange a geological sequence that layers sediment above your remains. You will need to accumulate sufficient layers to create pressure that forms sedimentary rock. It is important to arrange these in a way that means minerals can leach through the rock. This will dissolve your bodily tissues and allow the mineral leachate to replace them. Then, you need to ensure that erosion removes enough of the rock above you that you stand a chance of being found. While the gold of your ID tag would survive this, an inscription on it wouldn't.

Alternatively, you could use the Roman method. Lie in the path of a pyroclastic flow until thoroughly cooked and covered with 5 metres of ash. You would be discovered as a void in the ash and someone would have to fill your void with concrete to recreate your likeness.

Or you could follow the instructions in the *New Scientist* book *How to Fossilise Your Hamster* and scale up.

Mike Follows
Sutton Coldfield,
West Midlands, UK
In order to become a fossil, your body would need to be completely buried immediately after you died. A low-energy environment like a river delta or the bottom of a lake would ensure that your body isn't

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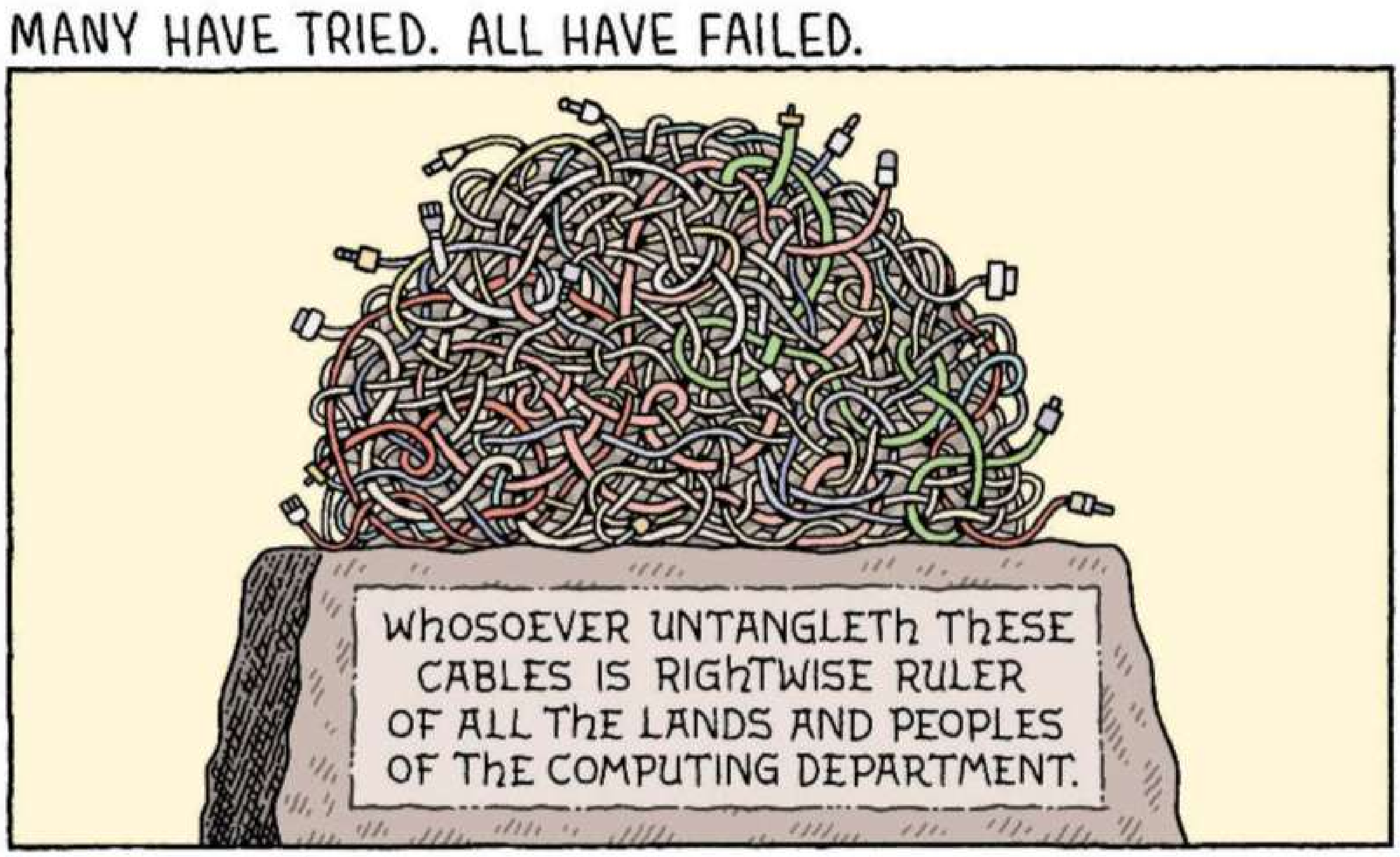
Tom Gauld

for New Scientist


MANY HAVE TRIED. ALL HAVE FAILED.
WHOSOEVER UNTANGLETH THESE CABLES IS RIGHTWISE RULER OF ALL THE LANDS AND PEOPLES OF THE COMPUTING DEPARTMENT.

disturbed. These surroundings would also need to be very low in oxygen, in order to put your body beyond the reach of microorganisms or animals that could eat or dismember your remains and to halt or delay its chemical decomposition.

Possibly the best place for this would be under the very fine silt of the abyssal plain, which makes up about half of the ocean floor. Burial deeper than half a metre is advisable, so your body is beyond the reach of burrowing creatures like worms. Marine snow – organic debris falling from shallow water above – would then accumulate, increasing the pressure on your body.

You would need at least 200,000 years for fossilisation to work its magic, so you would need to avoid a subduction zone or other geologically active sites. However, there might be a problem relocating your fossilised body – or, worse, a future generation of your family might forget to pass on the knowledge of your fossil's location.

> **"To turn yourself into a fossil, you would need at least 200,000 years for the fossilisation process to work its magic"**

An alternative strategy might be to collect enough tree resin to become preserved in amber. If you simply want to be conserved, then being launched into outer space or hidden in the permanent shadow of a lunar crater might be an option.

Gold is chemically inert, so a plaque made of it would survive, provided it wasn't physically abraded. However, the screws used to attach it to the rock might corrode, or the rock itself might chemically weather, so I would be surprised if a plaque were still attached to a rock after a few million years.

Perhaps the best way of being "fossilised" is to pass on your genes and accept that natural selection will modify your genome.

Hillary Shaw
Newport, Shropshire, UK

There are three main problems in turning yourself into a fossil.

The fossilisation process is the first. To accomplish this, just before you die, get into an underground chamber where you can pull a rope to flood the place with anoxic mud. Then you stand a good chance of becoming a well-preserved fossil, complete with your gold identification plate.

Your second problem is whether any sentient being could interpret the words on the gold plate in millions of years time. The use of pictures and symbols like arrows should help overcome this issue.

The biggest problem is where to carry out this fossilisation. You need somewhere that won't be subducted or buried beneath a new mountain range, ocean or ice sheet, but there are conflicting models of what Earth's geography will be like millions of years from now. Personally, I would go for the middle of the Canadian Shield, where bits of crust from billions of years ago still persist. ▮

Answers

Quick quiz #164
Answers

1 Titan, which orbits Saturn
2 The wind
3 The Japanese spider crab (*Macrocheira kaempferi*)
4 John Harrison
5 Three: oxygen-16, oxygen-17 and oxygen-18

Cryptic crossword #89 *Answers*

ACROSS 7 Tomato, **8** Alkane, **9** Toad, **10** Treatise, **11** Sod's Law, **13** Broth, **15** Sense, **17** Tadpole, **20** Sharpest, **21/5** Pond skater, **23** Tarmac, **24** Motown

DOWN 1 No-no, **2** Caddis, **4/3** Water boatman, **6** Inositol, **12** Overhead, **14** Pastime, **16** Shrimp, **18** Pupate, **19** Leech, **22** Newt

#179 Martian food
Solution

Let's call the sustainable population of Mars "P".

P people consume the amount of grass that grows in any period. 40-P people consume the remaining stock in 20 days. 20-P people consume the remaining stock in 60 days.

So 20 x (40-P) = 60 x (20-P) and hence P = 10.

(This is a modern variant of a puzzle first set by Isaac Newton, which involved oxen grazing on pasture.)

Hair-raising heirloom

Tidying the stationery cupboard throws up many archaeological treasures, but nothing so exciting, or terrifying, as the discovery made by a gentleman sorting through his deceased brother's attic in Kent the other day. He found a head.

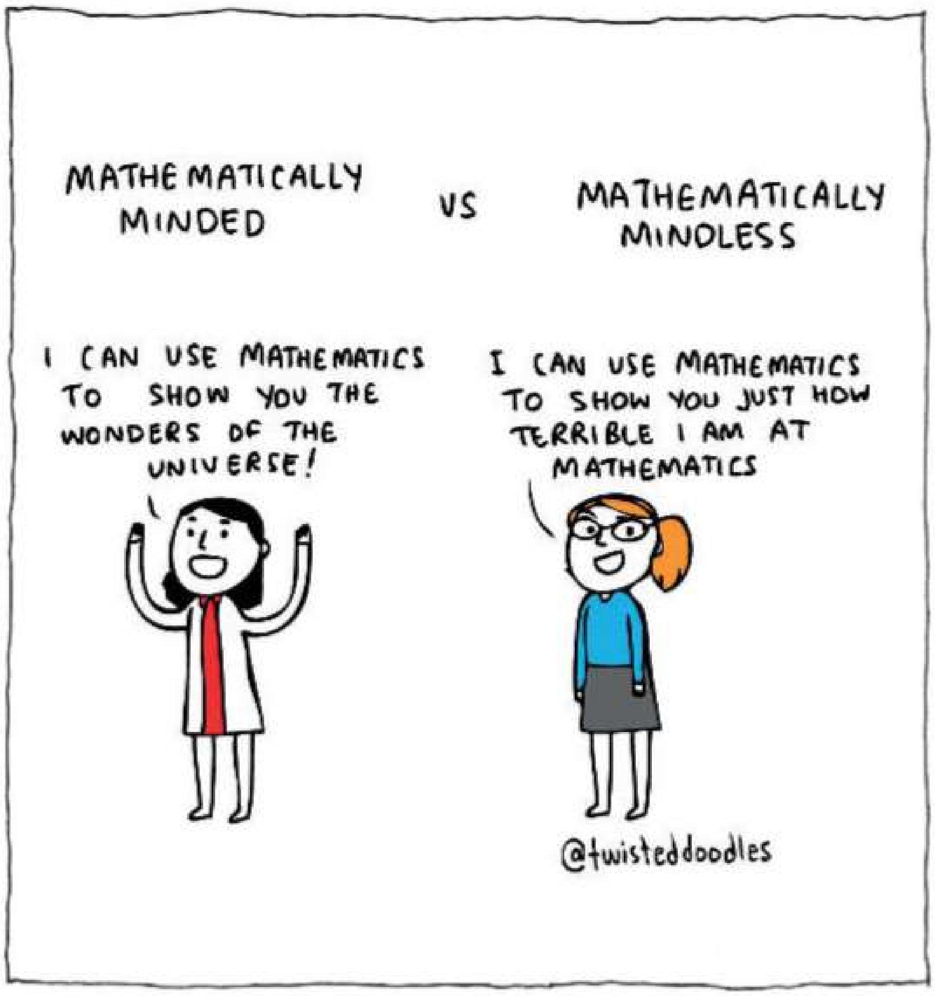
This Egyptian mummy's remains, brought to England as a souvenir, must have been passed down the family line for several generations. You would think it might have come up in conversation now and again. But no: the discoverer, who has gifted the grisly object to Canterbury Museums and Galleries, says he knew nothing about it. A CT scan has established that the head is female, and more detailed research should be able to tell us much about her life, health and diet – rather less about how she ended up shrouded in family secrecy in a Kentish attic.

Delayed justice

Little mystery attaches to the fate of Elizabeth Johnson, convicted of consorting with the devil in 1693 in Salem, Massachusetts. Johnson, though branded a witch, wasn't executed, and maybe that is why, when the colony passed a bill in 1711 overturning the witchcraft convictions, her name got left off the list. She lived into the mid-1700s – under what cloud one can only imagine – and was buried in an unmarked grave.

Her story attracted the attention of Massachusetts teacher Carrie LaPierre and her eighth-grade civics class, and, says *Smithsonian Magazine*, inspired their campaign to get Johnson exonerated. The bill passed on 28 July. The wheels of justice ever turned slowly – but 329 years might be some sort of record.

Twisteddoodles *for New Scientist*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@twisteddoodles

Got a story for Feedback?

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Consideration of items sent in the post will be delayed

The waiting game

On the same day, waiting of an altogether more cheerful sort was being anatomised in the *Journal of Experimental Psychology*. Aya Hatano and her team at Kyoto University may have staged the cheapest and simplest experiment in the history of psychology by observing groups of 259 university students waiting in a room. Their results were startling: "Across six experiments, we consistently found that participants' predicted enjoyment and engagement for the waiting task were significantly less than what they actually experienced," the team explains. Those volunteers who were permitted to access distractions stabbed away at their mobile phones – and yet emerged no happier than those left mulling their own thoughts. Vindication is sweet for Feedback, whose Nokia 8110 was last charged in 1996.

Revenge is salty

So here we are, in the stationery cupboard, without a mobile phone, thinking. In this meditative state, Feedback's attentions are drawn ineluctably inwards. As in: are there any snacks about the place?

The Sun's report on the work of Mathias Clausen and his team at the University of Southern Denmark was met with a degree of glee here. Apparently, if you marinate jellyfish in alcohol, then smother them in salt and vinegar, they come out all crunchy and tasting rather like pork scratchings. Delicious.

Tasteless beverage

And what better to wash them down with than a nice cup of condom juice? You can let go of your pearls, it isn't what you think (but it isn't much better). According to CNN's News18, a bunch of lads in Durgapur, India, have discovered that if you boil up flavoured condoms, the aromatic compounds break down to alcohol. Well, of a sort: according to the report, Dheeman Mandal at Durgapur Divisional Hospital says one of the compounds is also found in Dendrite, a glue abused by solvent sniffers. For those contemplating a pot of simmering rubbers, be advised the process also releases some very harmful toxins, of course.

Space snack

Clearly, humans will go to great lengths for an *amuse-bouche*, but 4.2 light years seems a very long way to go for a slice of spicy Spanish sausage.

On 31 July, Étienne Klein, director of France's Alternative Energies and Atomic Energy Commission, posted a photograph of a slice of reddish-orange chorizo to Twitter with a whimsical caption claiming it to be a snap of Proxima Centauri taken by the James Webb Space Telescope.

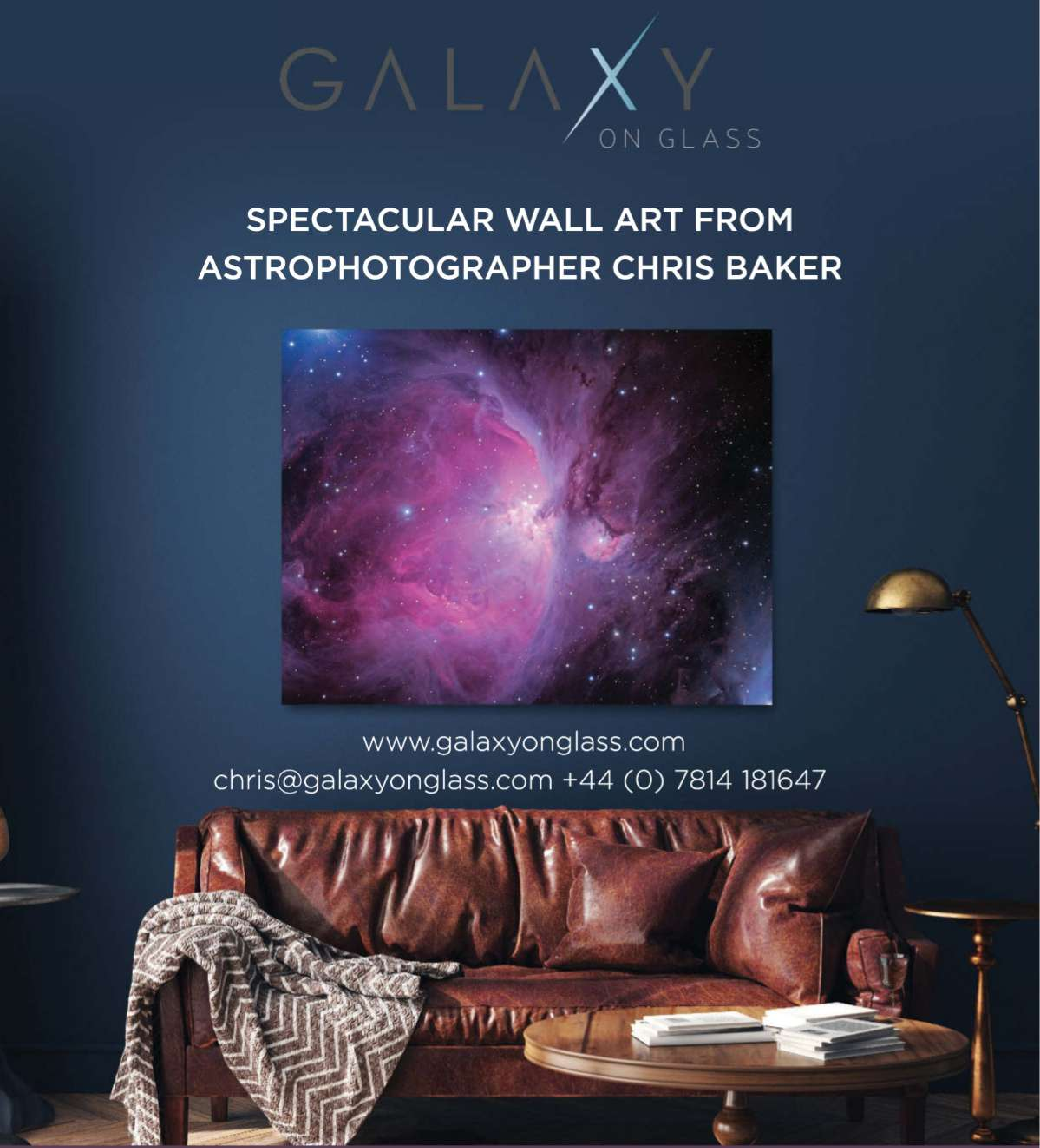
Space.com has it that the post then promptly blew up, the photo garnering 19,000 likes and more than 3000 retweets in a matter of hours. Klein issued a hurried retraction: "According to contemporary cosmology," he wrote, "no object belonging to Spanish charcuterie exists anywhere but on Earth."

Just as long as we are clear the moon is made of cheese, right?

Legal bun fight

After the jellyfish crisps and stellar sausage, some coffee would be nice, if only to wash away the news from Durgapur. A cup may soon arrive free of charge, courtesy of Canadian coffee-house chain Tim Hortons, which is trying to settle a class action lawsuit after customers found the company's app had been harvesting data from their mobile phones for over a year.

The proposed settlement offers a free hot beverage and a free baked good to all eligible app users. Given the other refreshments on offer in this week's column, Feedback is inclined to accept.



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